TITANIC

The Ship Magnificent

Volume One: Design & Construction

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Bruce Beveridge
Scott Andrews, Steve Hall
Daniel Klistorner, Art Braunschweiger

The
History
Press

Dedicated to Larry Jibson
1955–2004

I must go down to the sea again, to the lonely sea and the sky,
And all I ask is a tall ship and a star to steer her by,
And the wheel's kick and the wind's song and the white sails shaking,
And a gray mist on the sea's face and a gray dawn breaking.

John Mansfield, Sea Fever

Frontispiece courtesy of Mark Chirnside, Daniel Klistorner and J. Kent Layton

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Foreword

Since the day *Titanic* passed into history, people have been writing books about the circumstances surrounding the loss of this great ship – who was to blame, who the passengers and crew were, how the ship sank and so on. And yet, little has been written about the great ship herself – the design, structural details and engineering of what is arguably the most famous ship ever built. One is hard-pressed to find anything containing more than a cursory description of the details of *Titanic*'s design and appearance, or how she was constructed. The exceptions to this statement may be found in literature contemporary to the ship's construction. There were publications dedicated, at least in part, to marine engineering at the time – most notably *The Shipbuilder*, *The Engineer* and *Engineering* – all of which featured articles on *Olympic* and *Titanic*. Subsequent but less well-known articles were written regarding her electrical outfit, sanitary fittings and supplemental equipment. If it were not for these contemporary references, the *Titanic* researcher would be hard-pressed to find detailed information about her construction and fittings. A great help, however, when researching the *Titanic*'s physical structure was the fact that she was built to meet the requirements set forth by the British Board of Trade, the overseeing government body for ship construction at the time. Thus, the rules and regulations of the 'B.O.T' could be drawn on for reference in writing this book, as well as those written in both Britain and the United States for the classification of an 'Emigrant Ship' (*Titanic* was built to conform to the regulations of both countries).

Unlike the major technical aspects of the ship which were fully covered in contemporary engineering journals, and details about the common fittings used aboard the *Titanic*, there is little information available to present to the modern reader when it comes to anything beyond the grandest of the ship's public rooms and deluxe staterooms. However, through vigorous research, we have been able to assemble an accurate, if at times somewhat cursory, picture of nearly all of *Titanic*'s internal spaces. It must be understood that few actual pictures exist of *Titanic*'s passenger accommodations, and none at all are known to exist of the crew's compartments. Of those interior pictures that do survive, most are from *Titanic*'s older sister, *Olympic*. It is on *Olympic* that the *Titanic* researcher must rely in order to learn of her interior decoration and fittings. Luckily, some general arrangement drawings of *Titanic* have survived, those being the First Class passenger plan given out at time of ticket purchase, the original Harland & Wolff General Arrangement plans, and the General Arrangement plan that was submitted by Harland & Wolff in 1915 for the American Limitation of Liability hearings in New York. Further small details have been gleaned from careful study of the testimony of *Titanic*'s passengers and crew. Sadly, the many dives to the wreck have yielded few new details regarding *Titanic*'s internal arrangement, primarily because nearly everything that might have provided any new revelations has been destroyed by time and the elements. (The beautifully etched privacy glazing found within some passenger areas, and the startlingly well-preserved timber and tile work within the Turkish Baths are notable exceptions.) Video and still photography of other more isolated areas of the interior that were explored may yet hold a few surprises, but these images have not been released to the public as of this writing.

Olympic's specifications and photographs, as well as her few surviving interior fittings, are the most valuable resource for the *Titanic* researcher. While *Olympic* and *Titanic* were not exact duplicates, the more critical structural differences between the two ships were subtle. Being that the two sisters were built side-by-side, they shared not only the same design, but were literally built from many of the same drawings, with the work on each ship being carried out by the same craftsmen. In fact, most of the major component parts, from keel to funnels, were ordered at the same time or within a few months of one another.

More information exists regarding *Olympic*'s later years than from her pre-First World War service. Although her basic arrangement remained unchanged, *Olympic* underwent quite a few alterations after 1913. Therefore, it was with great joy that the authors were able to procure a copy of Cunard naval architect Leonard Peskett's private notes on *Olympic*, which he recorded while traveling on her from New York to Southampton from August 19 to August 25, 1911, *Olympic*'s third voyage. This document, which addresses many technical aspects of the ship, is very important because it was written many months prior to *Titanic*'s completion, thus excluding any post-disaster alterations. Peskett's notes were, in fact, his professional observations of *Olympic*, and were to play a significant role in the final design and outfitting of the *Aquitania*.

At the end of *Olympic*'s career, most of her internal fittings were put on the auction block. The catalog of *Olympic*'s fittings, which were auctioned off at The Palmers Works at Jarrow-on-Tyne by the firm of Knight, Frank, & Rutley in 1935, has become an invaluable reference for those researching *Titanic*'s interior details. However, the process of discerning which fittings were original to the ship and which were added later in her career is not for the novice and even those who are serious *Titanic* historians can be led astray. It is simply not possible to determine with complete certainty *Titanic*'s exact internal furniture and decoration schemes. Many resources have also been lost to time, war, or the overzealous spring cleaner. And, then, there are other documents that have fallen into the hands of private collectors who, for reasons known only to themselves, simply will not allow release of the information contained therein, even for a price.

The authors of this book have earned a reputation in the *Titanic* community for being staunch and aggressive researchers. No one knows, or can ever know, everything about this ship. We welcome comments and new information, and welcome the opportunity to update the information in this book at the next printing. However, erroneous information about *Titanic* has and continues to appear in print, and for that reason we cannot accept information on faith alone. Proof, whether written or photographic, must be available to substantiate any new or corrected information submitted.

Acknowledgements

The authors would like to thank, in no specific order:

Karen Signell Andrews for editing the preliminary drafts;

The British *Titanic* Society, which bestowed an honorary lifetime membership on Bruce, and which has always been there to provide him inspiration and guidance;

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The late Josha Inglis for his rare photos; Stewart Kelly for his interior woodwork photos; Günter Bäbler for his color images; Bernhard Funk and Steve Rigby for their dive footage and for their encouragement;

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Malcolm Shifrin for his information on Turkish Baths.

Mark Warren and the Northwestern University Engineering Library for the photographs from *Engineering*, *The Engineer*, *The Shipbuilder*, *The Electrician*, and other technical journals of the period;

Mark Darrah for the use of his original copies of *Engineering* and *The Engineer*;

Mark Chirnside for his contributions of original archival material including Cunard naval architect Leonard Peskett's report on *Olympic* which he discovered and generously shared;

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All photographic images are credited to the individuals from whom we secured them. In some cases, copies of original period images held by private collectors have been donated for use with the specific request that the the contributor remain anonymous, and these have been credited to 'authors collection' by agreed arrangement. In other cases, photographs were obtained years ago from various individuals whose names were not recorded. If we have unintentionally omitted credit to anyone for their contribution, we hope the omission will be forgiven. We will be glad to acknowledge anyone inadvertently omitted in future reprintings where possible.

Introduction

It is *Titanic*'s close association with her older sister *Olympic* that brought about the title of this book. Maritime historians will immediately recognize 'The Ship Magnificent' as the advertising phrase used for *Olympic* in White Star Line brochures later in her career. Such catchphrases were created for some of the other great liners as well. Because *Titanic*'s career was cut short with her demise on the morning of April 15, 1912, after striking an iceberg in the North Atlantic on her maiden voyage, she never had the opportunity to carry such a phrase of distinction. Given the fact that these two ships were near-identical twins, I have chosen to use *Olympic*'s catchphrase for this book.

The practices used in the shipbuilding of 1912 were, in some ways, similar to those of shipbuilding in the twenty-first century. However, as we forge deeper into the 'Information Age', the few remaining holdovers from times past will surely be replaced, if it hasn't happened already. Shipbuilding during the first part of the twentieth century was an industry in a state of constant change. Along with new patents and technology came a seemingly endless string of better and bigger vessels. *Titanic* was not, however, an example of groundbreaking, state-of-the-art naval architecture in anything other than her size. Her design, engines, interior decorations and other fittings had all been tried and tested on previous Harland & Wolff ships. Though *Titanic* was built during a time of transition at the turn of the twentieth century, arc welding – the technical innovation that would eventually revolutionize steel shipbuilding – was still in its infancy and not trusted for structural purposes. Steel-plate welding had been introduced to the management of Harland & Wolff by the Thermite Company in 1907, but was hardly used. *Titanic* was, therefore, a steel-and-iron ship held together almost entirely by rivets. The Ulster Folk and Transport Museum has appropriately termed the era as being one of 'Steel Ships and Iron Men'.

This book is a compilation of information gathered over the course of many years. Many of the books, photos, plans, advertising brochures, articles and notebooks consulted in writing this book reside in my personal archives, and in the personal archives of my co-authors. Much additional information was graciously offered from the personal archives of a number of like-minded ocean liner memorabilia collectors who share the belief of the authors that their privately held information should be presented for the appreciation and edification of the ship enthusiast everywhere. A great deal of insight was also gained from examining the artifacts raised from the *Titanic*'s wreck.

In some cases, where gaps existed in the available data, the information presented in this book was obtained from British works on naval architecture, marine engineering and ship construction that are contemporary to the period. Similarly, every effort has been made to fill in any gaps in the visual record. In certain instances, where a photograph or drawing of a specific feature or area was not available, references on other ships of the period were consulted. Pictures and illustrations of portions of ships such as the White Star Line's *Oceanic* and the Cunard liner *Aquitania* were used – all clearly marked with the identity of the ship to which they actually belong – and have proven invaluable in providing an impression of how some of these undocumented areas of the White Star trio appeared.

What has been accomplished in this offering is an amalgamation of all of the authors' resources that are *Titanic*-, *Olympic*-, or *Britannic*-specific. In doing this, we have provided information taken from *Titanic*'s sisters that would have been relevant to our subject matter specifically, as the three ships were so much alike in many respects. Where general ship construction practices and equipment are presented, we have done our best, based on careful study, to present information that is specific to the *Titanic*. However, in numerous cases we felt it worthwhile to broaden the scope a bit, and address some of the many variations in shipbuilding practice in order that the reader might better understand the history of the subject.

Also reprinted in this volume is a set of General Arrangement plans that I created over the course of some two years. These are special to me because they were initially produced as a navigational key for a dive to the wreck in 2002 that never happened for a host of reasons. The room arrangements have been gleaned first and foremost from period plans of *Titanic* and then from *Olympic*. Notations with a single asterisk (*) indicate that the arrangement is based directly on *Olympic*; a double asterisk (**) indicates an educated guess based on *Olympic*. A key to the abbreviations and symbols to the plans appearing throughout can be found on p. 681.

Volume I of the book covers the details of *Titanic*'s construction and fittings by subject matter. There is necessarily some overlap, but for purposes of coherency the detailed discussion of a given section has been kept within a single chapter wherever possible. Volume 2 covers the layout of the ship deck-by-deck. A bibliography has been provided to list all the sources for all research material used, although because of the wide range of period resource materials employed, specific references as to sources have not been provided throughout the text. Where they do appear in some specific cases; they are referenced as numbered endnotes. In addition, endnotes have also been used when additional explanatory text is required.

The information provided herein is very technical in some areas. In order to treat each subject properly and to the extent desired, a great deal of technical nomenclature and nautical terminology is unavoidable. Many of the terms used are period shipbuilding terms, and have been included in the text intentionally. A glossary as well as illustrations have been provided to help in understanding the language used. We feel that this subject is better served, and a better sense of history is gained, by presenting this information in the vernacular used by shipbuilders of the past. It will also, it is hoped, evoke for the reader a sense of this era which has now all but passed from living memory.

When *Titanic* completed her sea trials in 1912, her sister ship *Olympic* – in service since the previous June – had already become an unqualified success. *Olympic* would go on to log an estimated 1.8 million miles steamed over twenty-four years of active service, and would earn the sobriquet 'Old Reliable'. *Titanic*, like her sister, was not only a marvel of technology, but a ship of unparalleled luxury – in every sense, a 'Ship Magnificent'.

Bruce Beveridge
February, 2008

Note: Unless directly credited, images are authors' collection.

IMAGES OF *TITANIC*: CONSTRUCTION TO MAIDEN VOYAGE

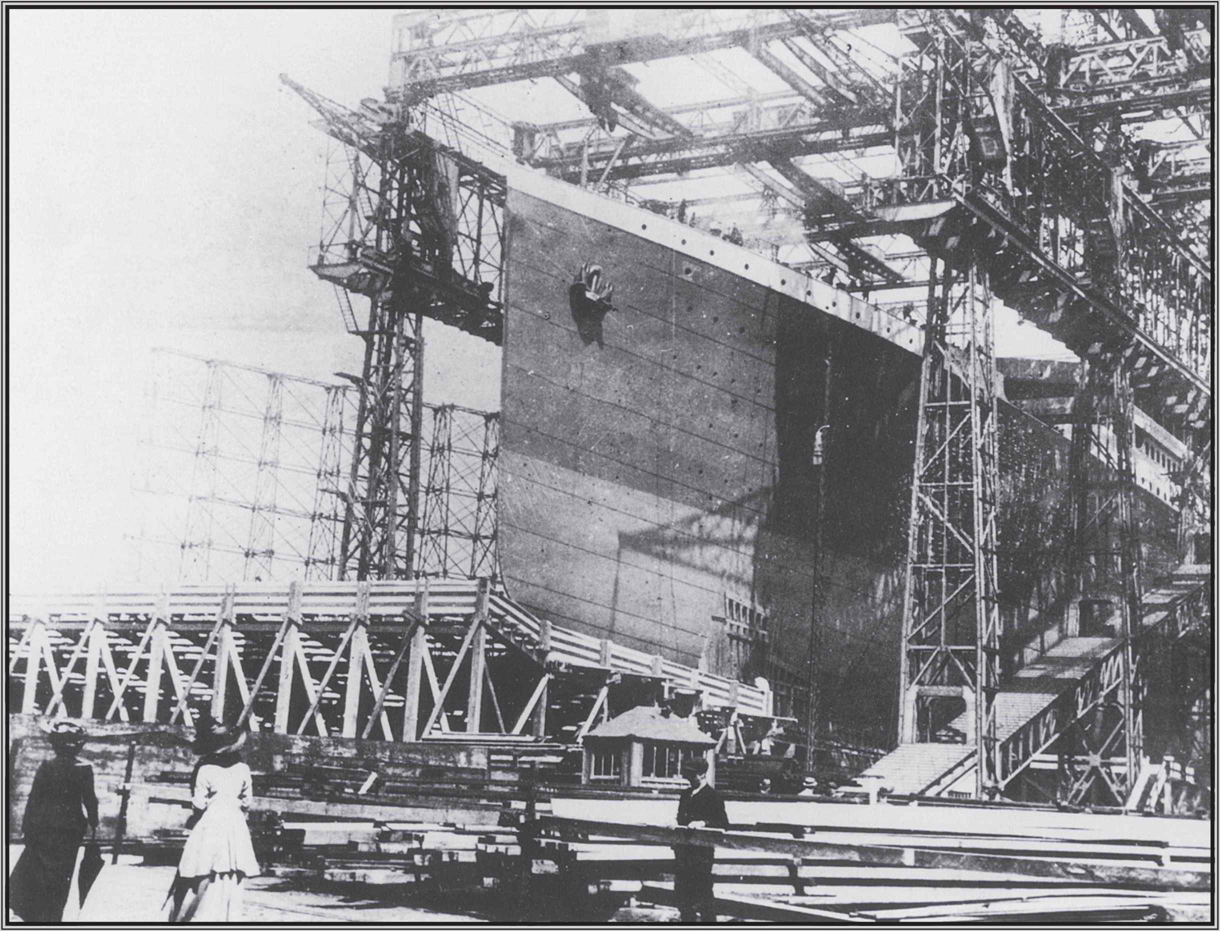
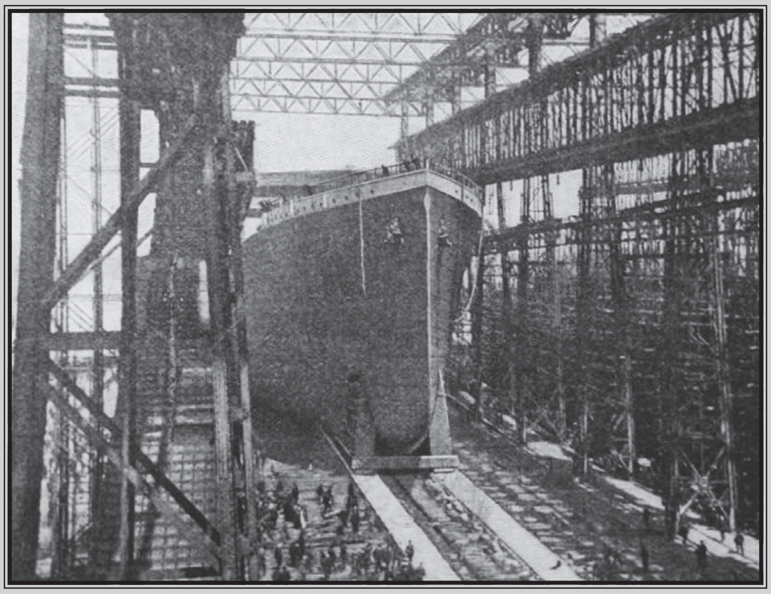
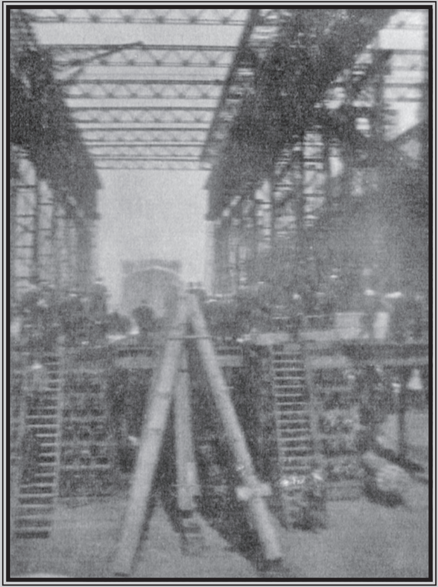


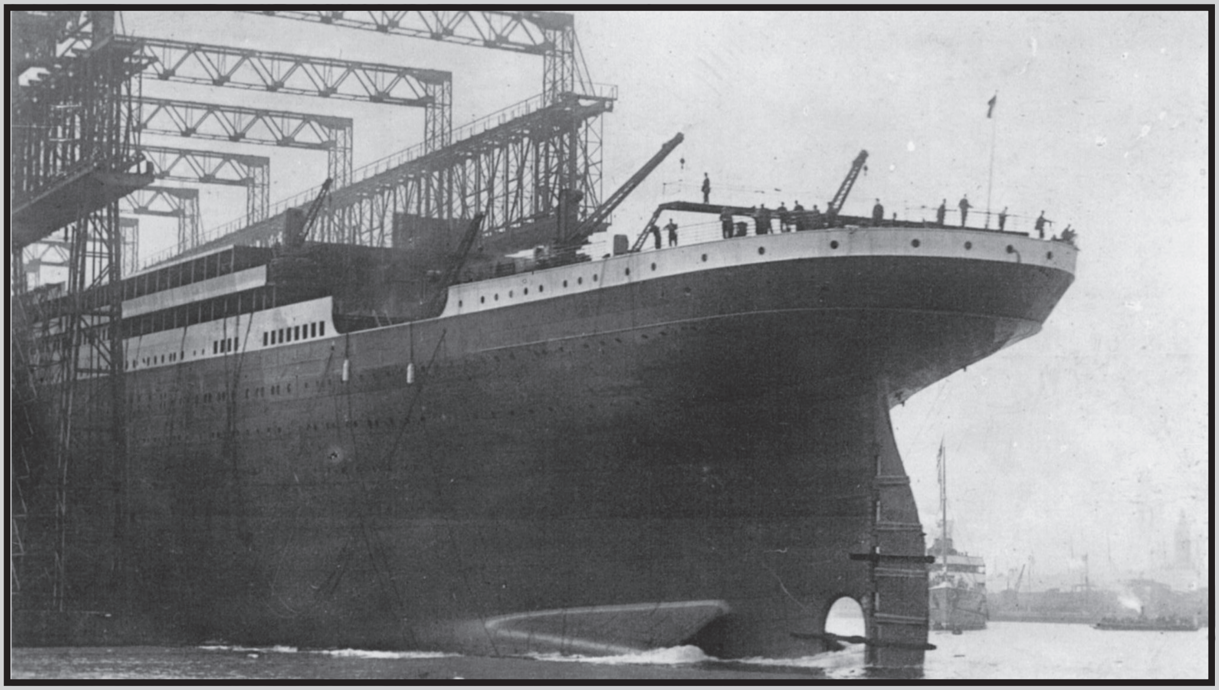
Fig. I In the final days prior to launch, a large viewing platform is constructed for officially invited guests to witness the event. *(R. Terrell-Wright collection)*



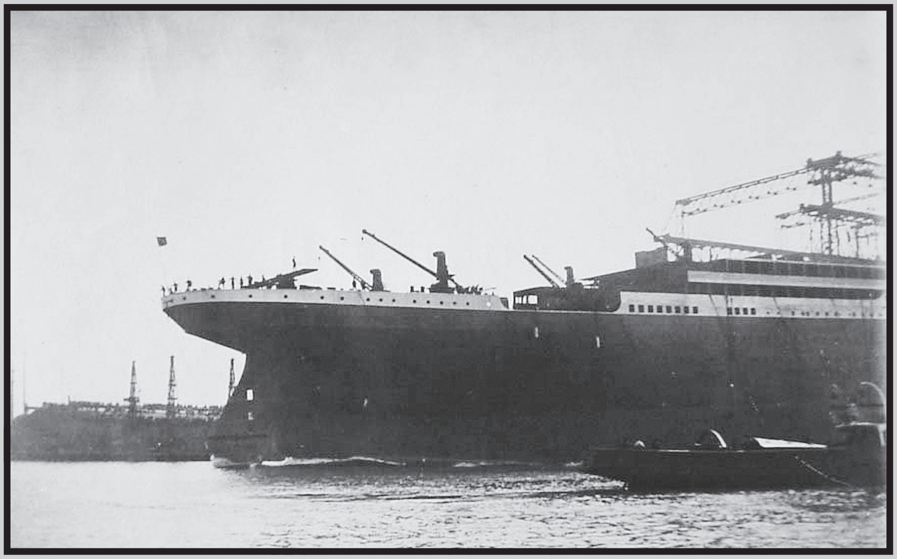


Above, left Fig. II Just after 12.16 p.m., *Titanic* slides effortlessly down the ways, cheered on by hundreds of yard workmen and spectators. *(R. Terrell-Wright collection)*

Above, right Fig. III A view of *Titanic,* taken from behind the observation platform as her bow slides into the River Lagan. *(R. Terrell–Wright collection)*



Above Fig. IV A port quarter view of *Titanic* as she enters the river. *(R. Terrell–Wright collection)*



Left Fig. V The launch as seen from *Titanic*'s starboard side. *Titanic* produced little wake as she entered the Lagan. *(R. Terrell–Wright collection)*

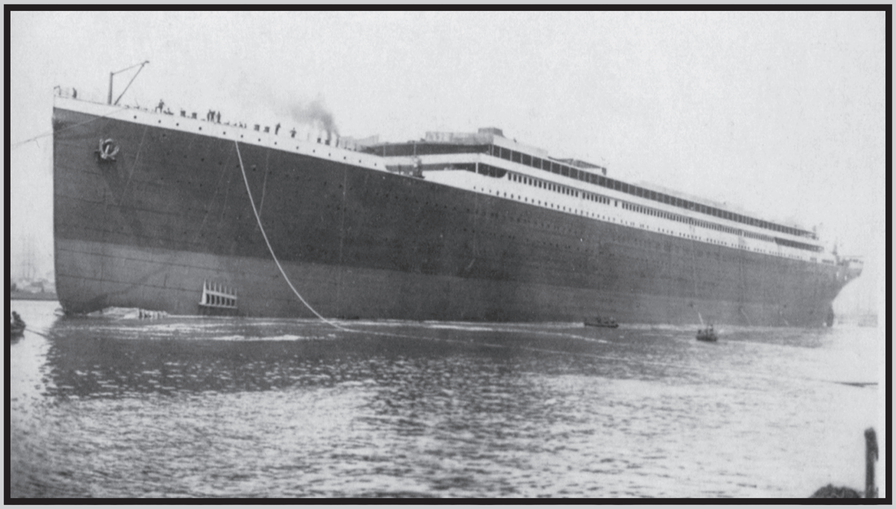
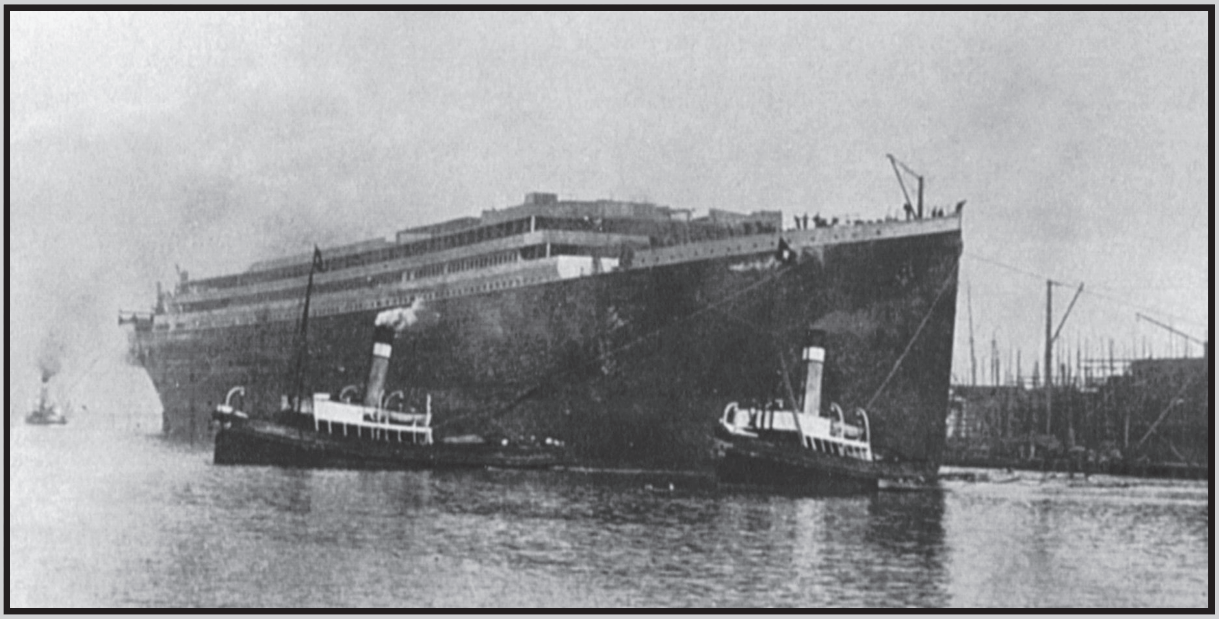
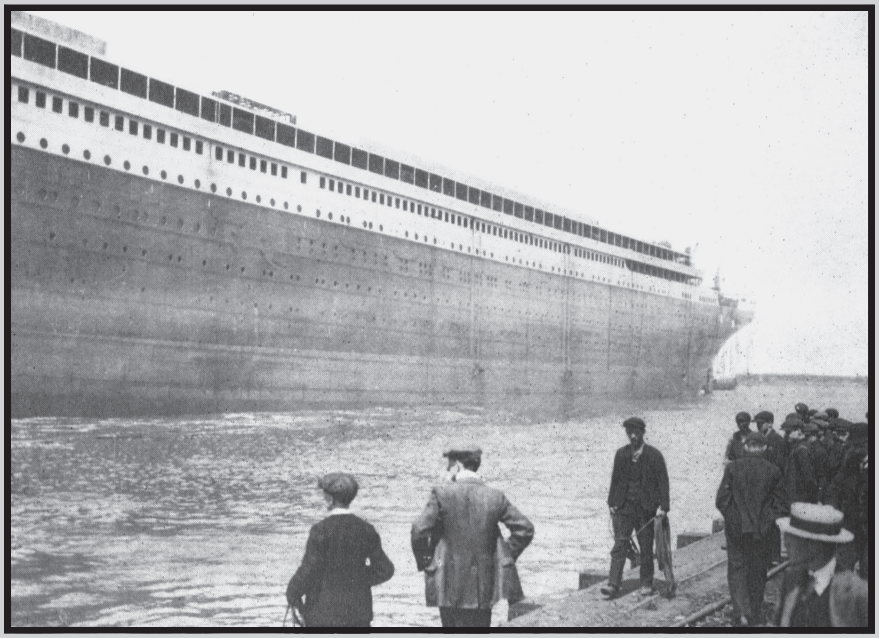


Fig. VI In this photograph taken immediately after launch, small boats crewed by yard workmen begin the removal of drag chains. *(R. Terrell–Wright collection)*



Above Fig. VII With drag chains and launch gear removed, yard tugs prepare to tow *Titanic* to the Fitting-Out Wharf. *(R. Terrell–Wright collection)*



Right Fig. VIII *Titanic* seen coming alongside the Fitting-Out Wharf later that same afternoon. *(R. Terrell–Wright collection)*

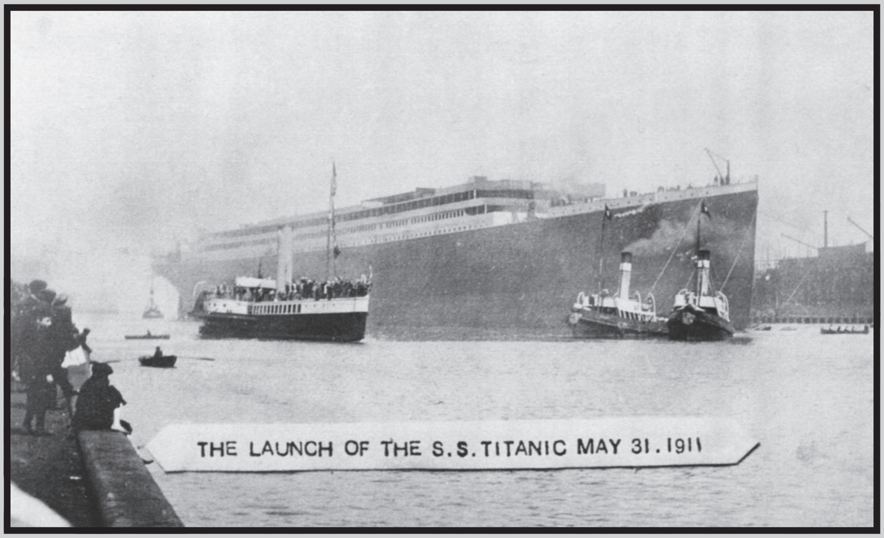


Fig. IX Viewed by a large crowd of spectators along the West Twin Wharf, tugs begin to move *Titanic* to the Fitting-Out Wharf. *(R. Terrell–Wright collection)*

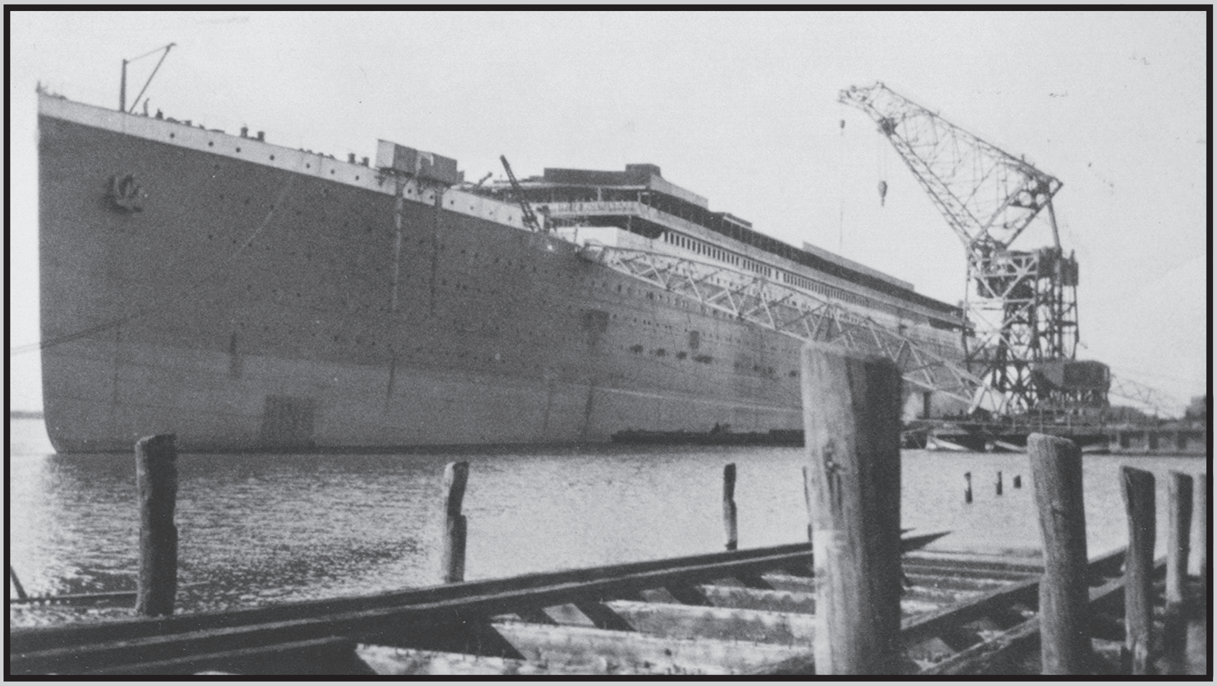
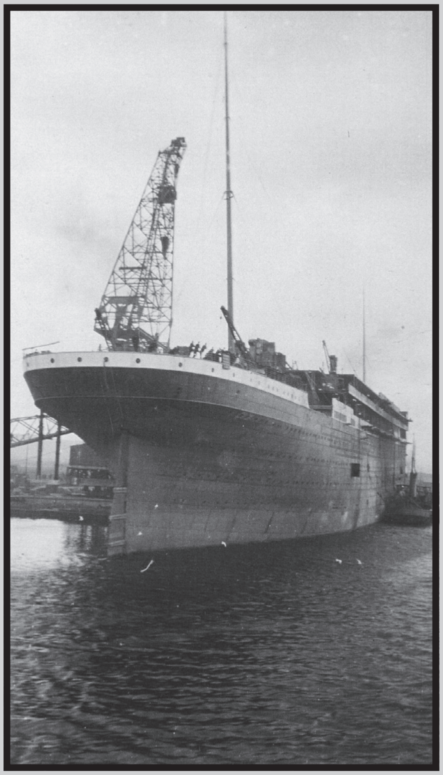
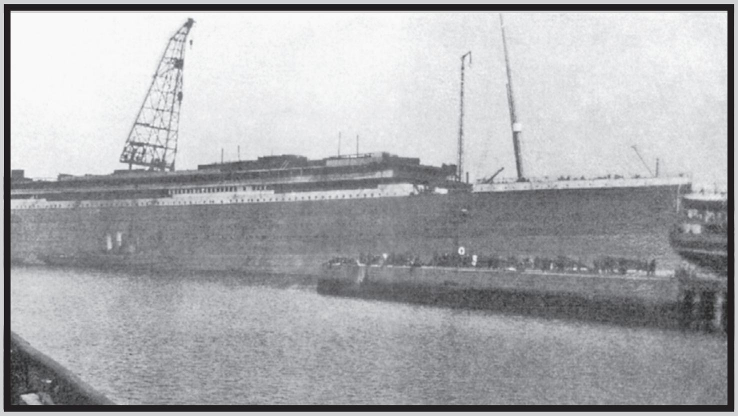


Fig. x A photograph taken of *Titanic* in early June. The ship is seen here tied up alongside the Fitting-Out Wharf. *(Ray Lepien collection)*

Right Fig. xi A starboard quarter view taken in late June, 1911. Platforms are seen along the side of the ship as the slimmer Utley's vertical sliding windows are being installed on B Deck. *(R. Terrell–Wright collection)*



Below Fig. xii A starboard view taken June 14, 1911. The foremast is now in place and alterations to B Deck have begun. *(R. Terrell–Wright collection)*



Opposite, below Fig. xvi A photograph taken of *Titanic* in early January, 1912. In the following week, the ship would enter the Thompson Graving Dock for the first time. *(R. Terrell–Wright collection)*

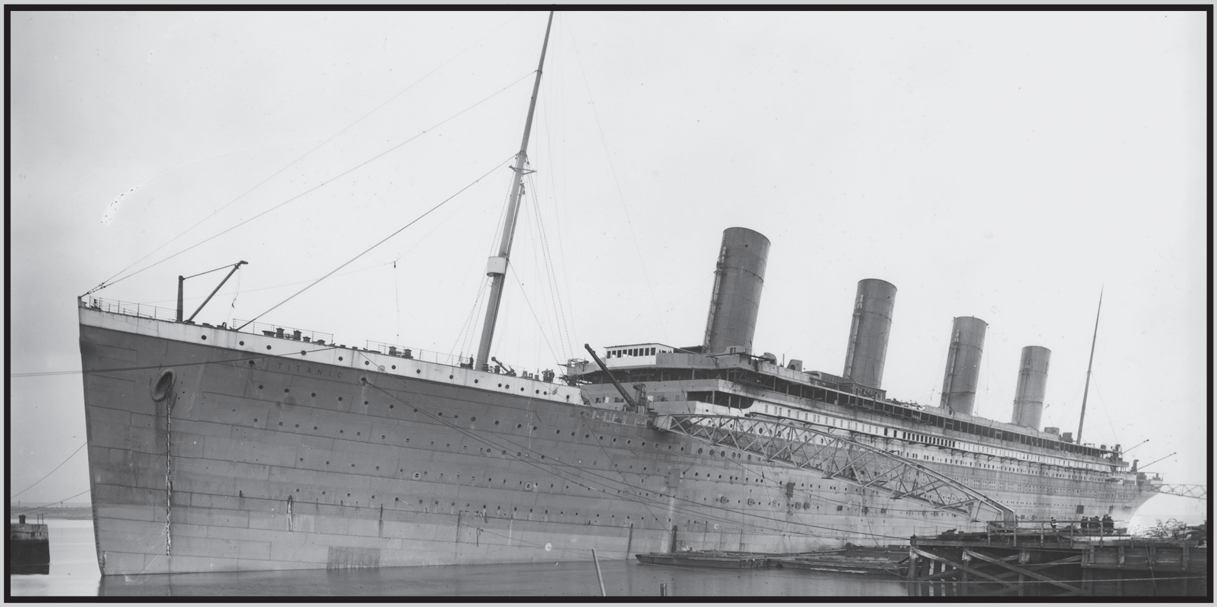
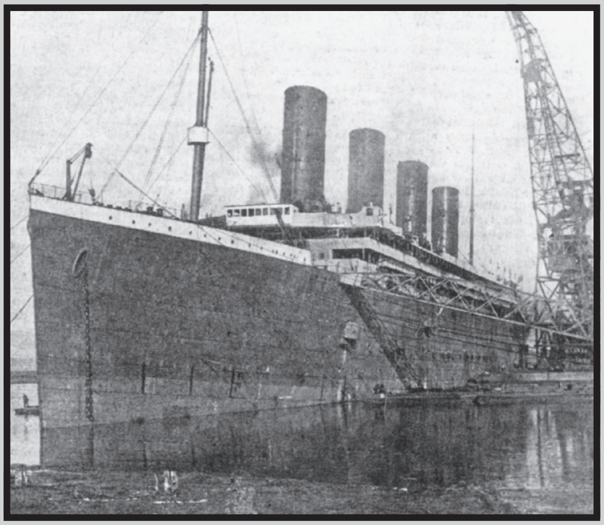
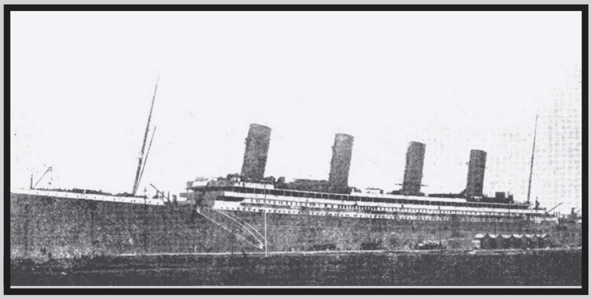


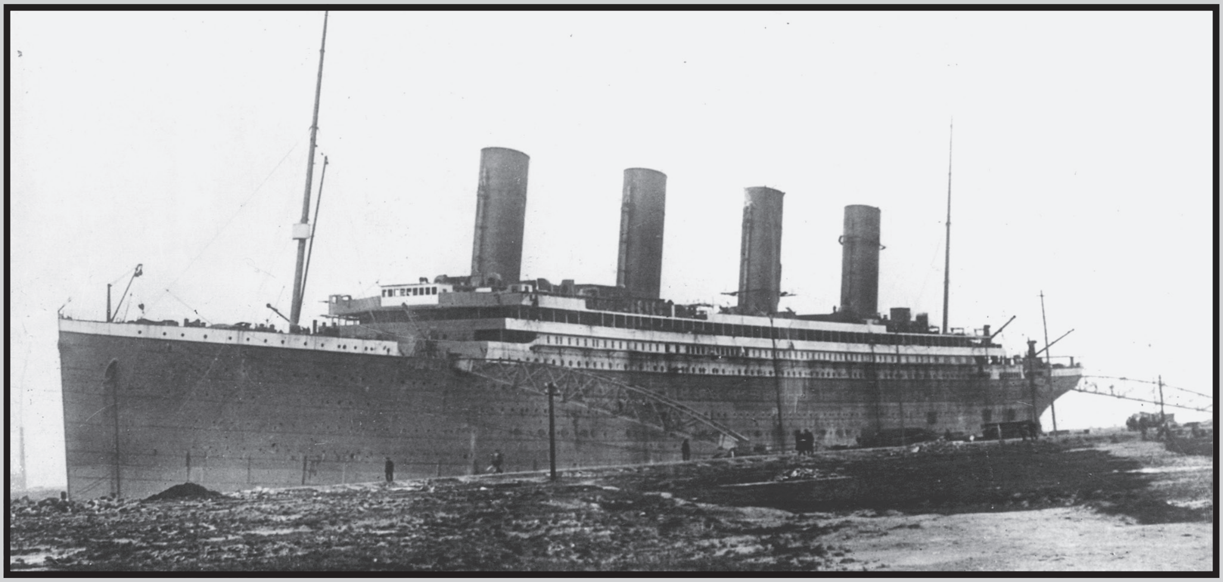
Fig. XIII Another view of *Titanic* tied up alongside the Fitting-Out Wharf, taken in January, 1912. The ship's funnels have now been fitted.

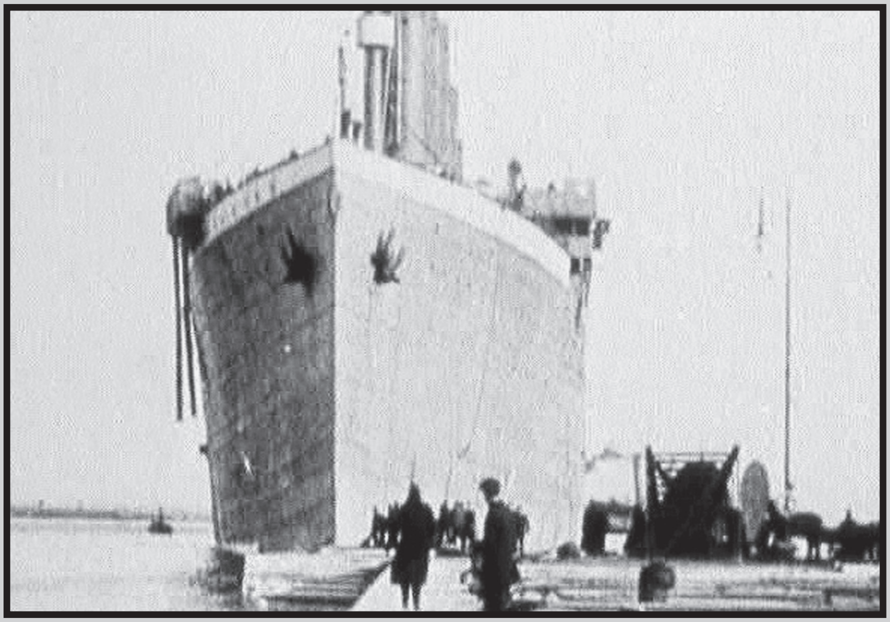




Above Fig. XV *Titanic* following the alteration to her external B Deck window configuration on the port side.

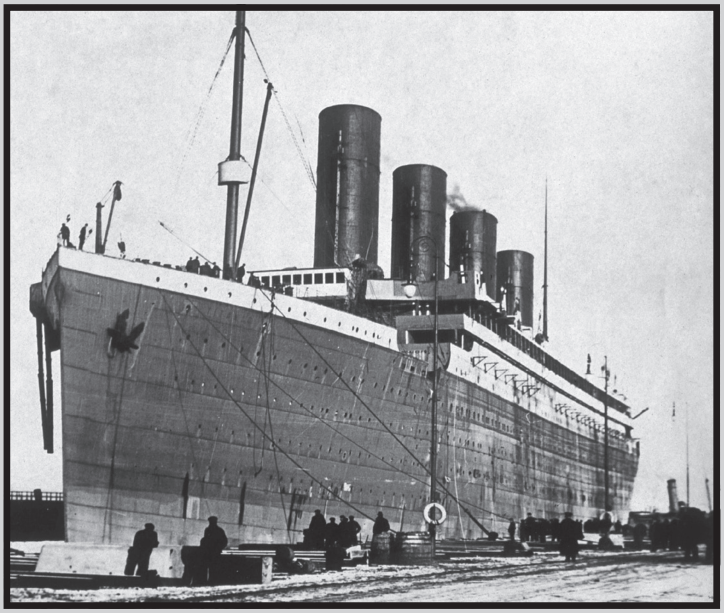
Left Fig. XIV *Titanic* sits idle and calm upon the water. Preparations will soon be made for her drydocking. *(R. Terrell–Wright collection)*

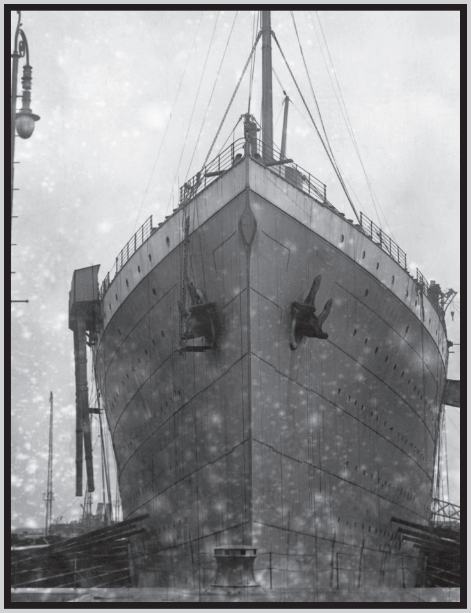




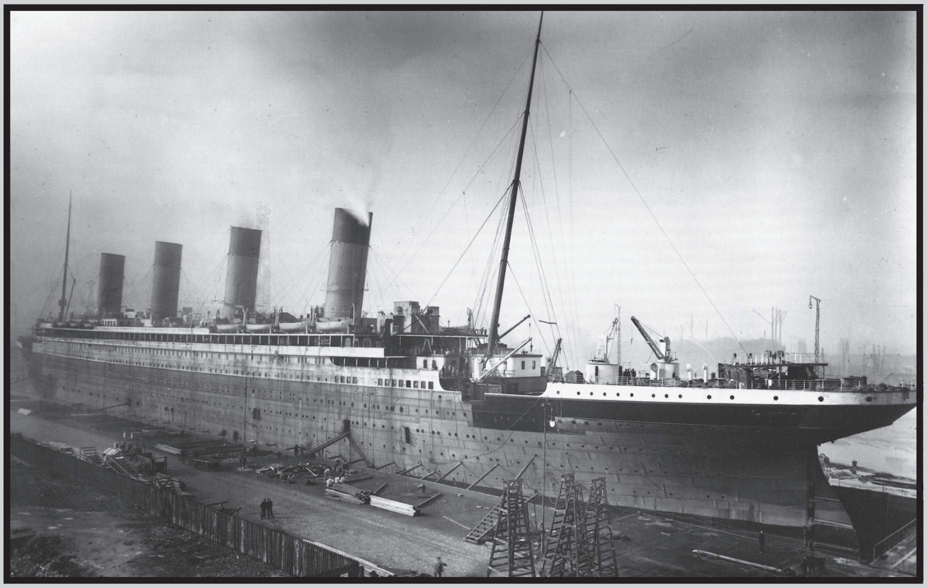
Left Fig. xvii *Titanic* preparing to enter the Thompson Graving Dock for the first time. Note the propeller blades on the dock.

Below, left Fig. xviii *Titanic* has successfully entered the Graving Dock; this would be the first of three visits she would make before final completion. *(Josha Inglis collection)*



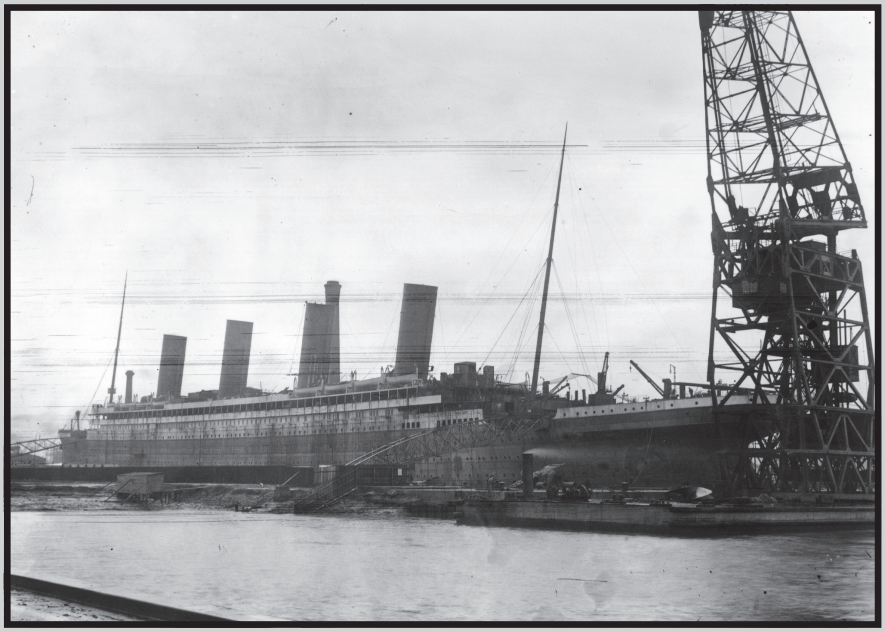


Above, right Fig. xix Rare bow view of *Titanic* taken in drydock, February, 1912.

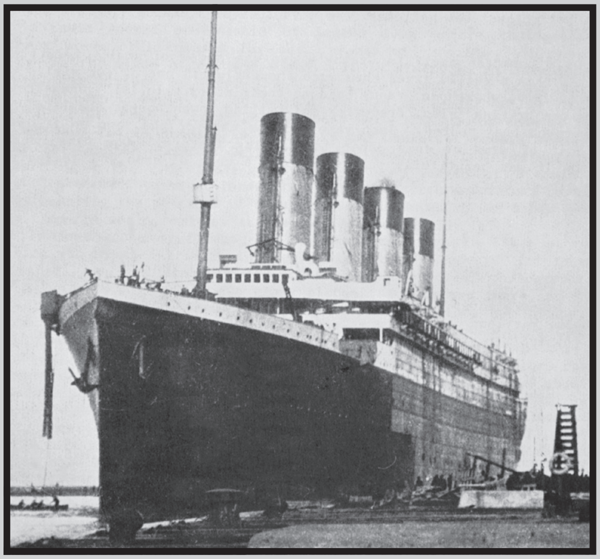


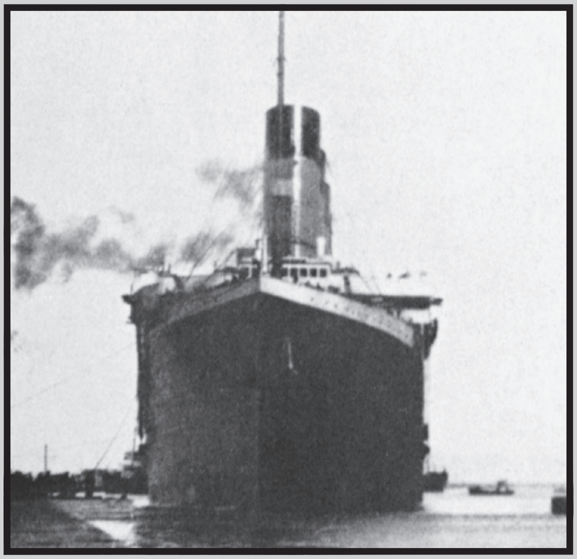
Left Fig. xx A rare port quarter view of *Titanic* taken from the yard's floating crane, March, 1912.

Right Fig. xxi A view of *Titanic* in drydock, taken from the Fitting-Out Wharf in February, 1912.



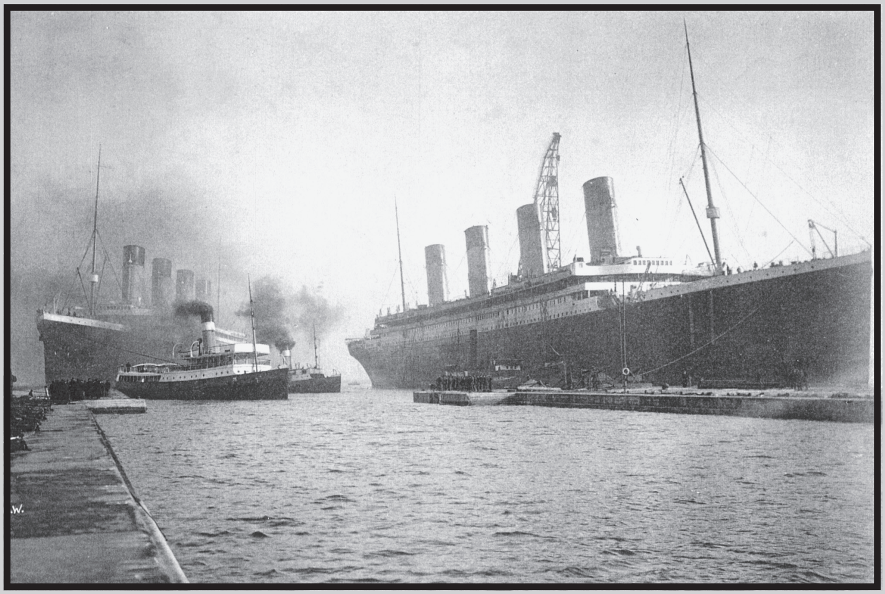
Below, left Fig. xxii On March 2, 1912, *Titanic* is seen being removed from the Graving Dock to make room for her sister *Olympic,* visible at the far right. *(Josha Inglis collection)*





Above, right Fig. xxiii Another view of *Titanic* being removed from drydock. *(Josha Inglis collection)*

Right Fig. xxiv *Olympic* preparing to enter the Graving Dock, March 2, 1912. In this photo *Titanic* is to the right. *(R. Terrell–Wright collection)*



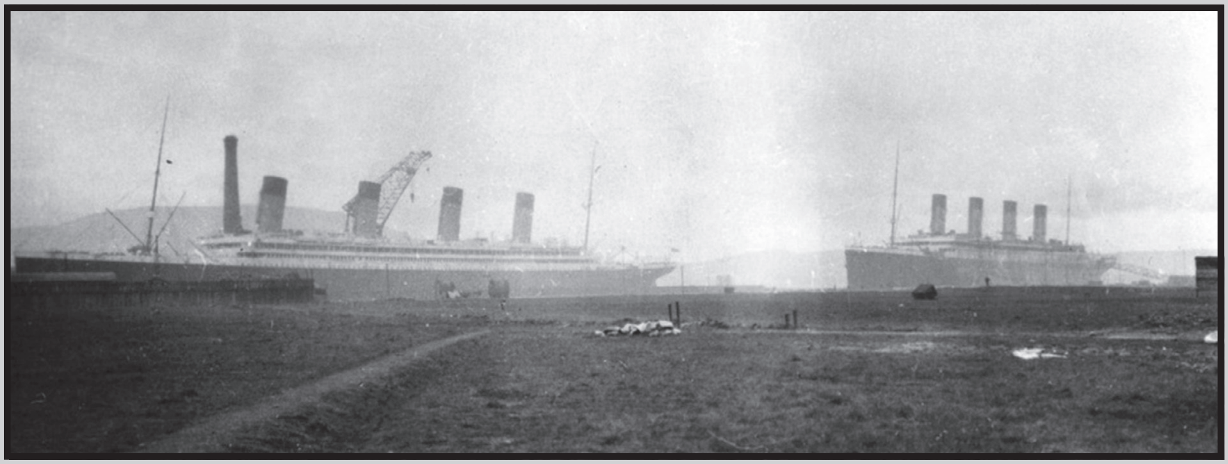


Fig. xxv *Olympic* and *Titanic* in echelon, with *Olympic* in drydock and *Titanic* astern. *(Josha Inglis collection)*

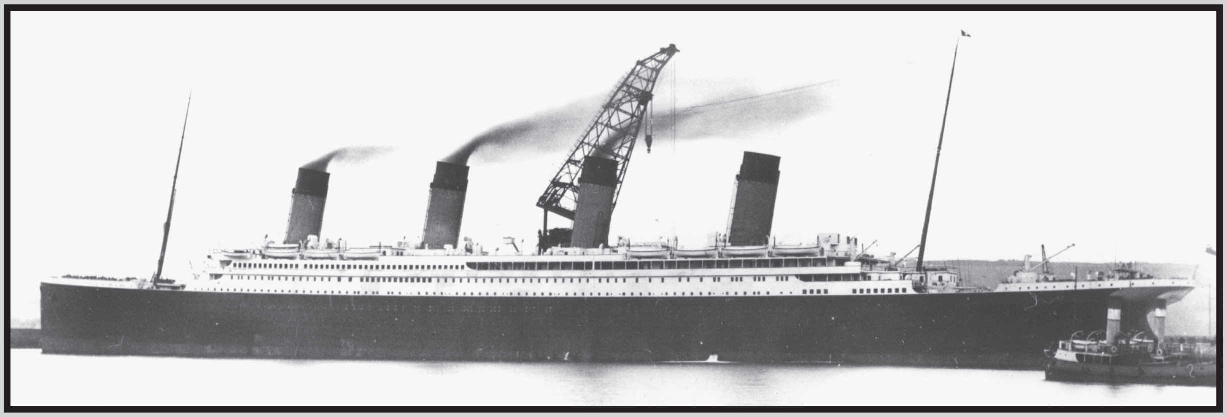


Fig. xxvi *Titanic,* April 1, 1912 – sea trials had been planned for this day, but were cancelled due to high winds.

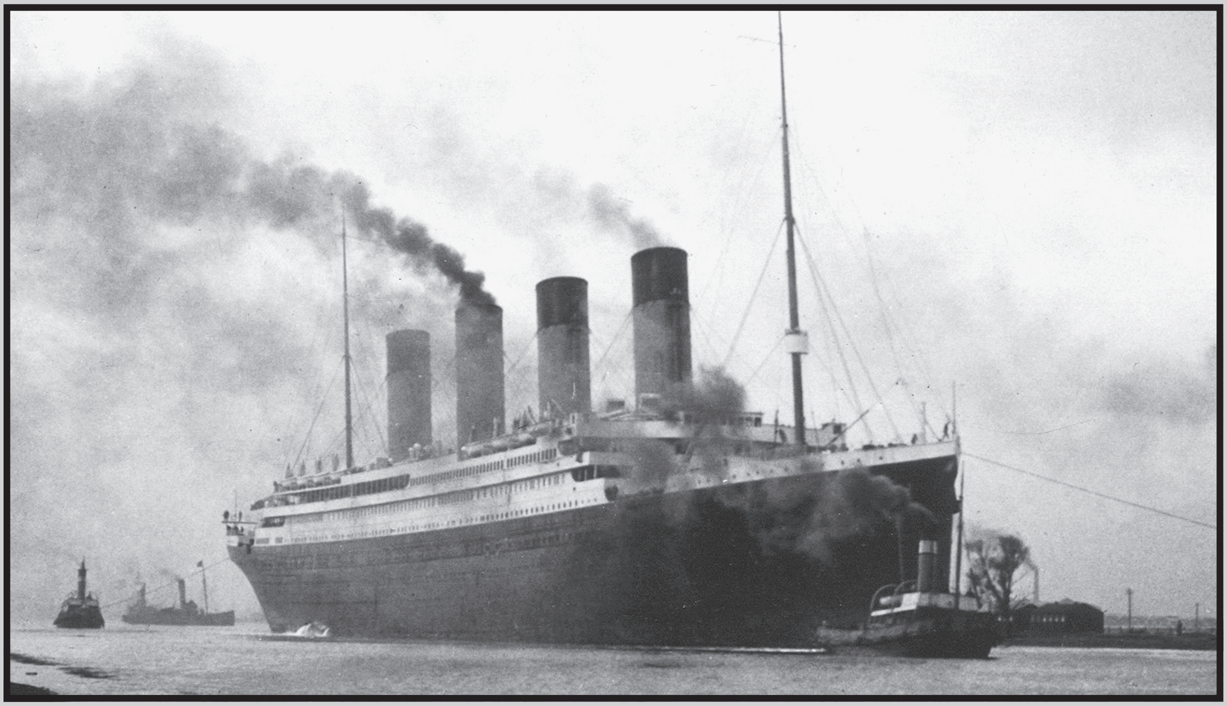


Fig. xxvii *Titanic* escorted up the Victoria Channel by tugs before her sea trials, April 2, 1912.

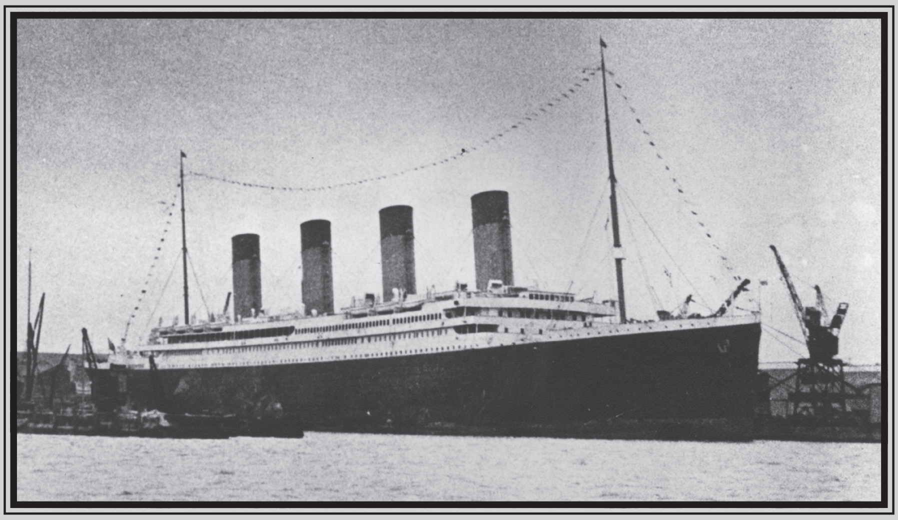


Fig. XXVIII *Titanic* is dressed out on the day she arrived in port, Thursday, April 4, 1912. *(R. Terrell–Wright collection)*

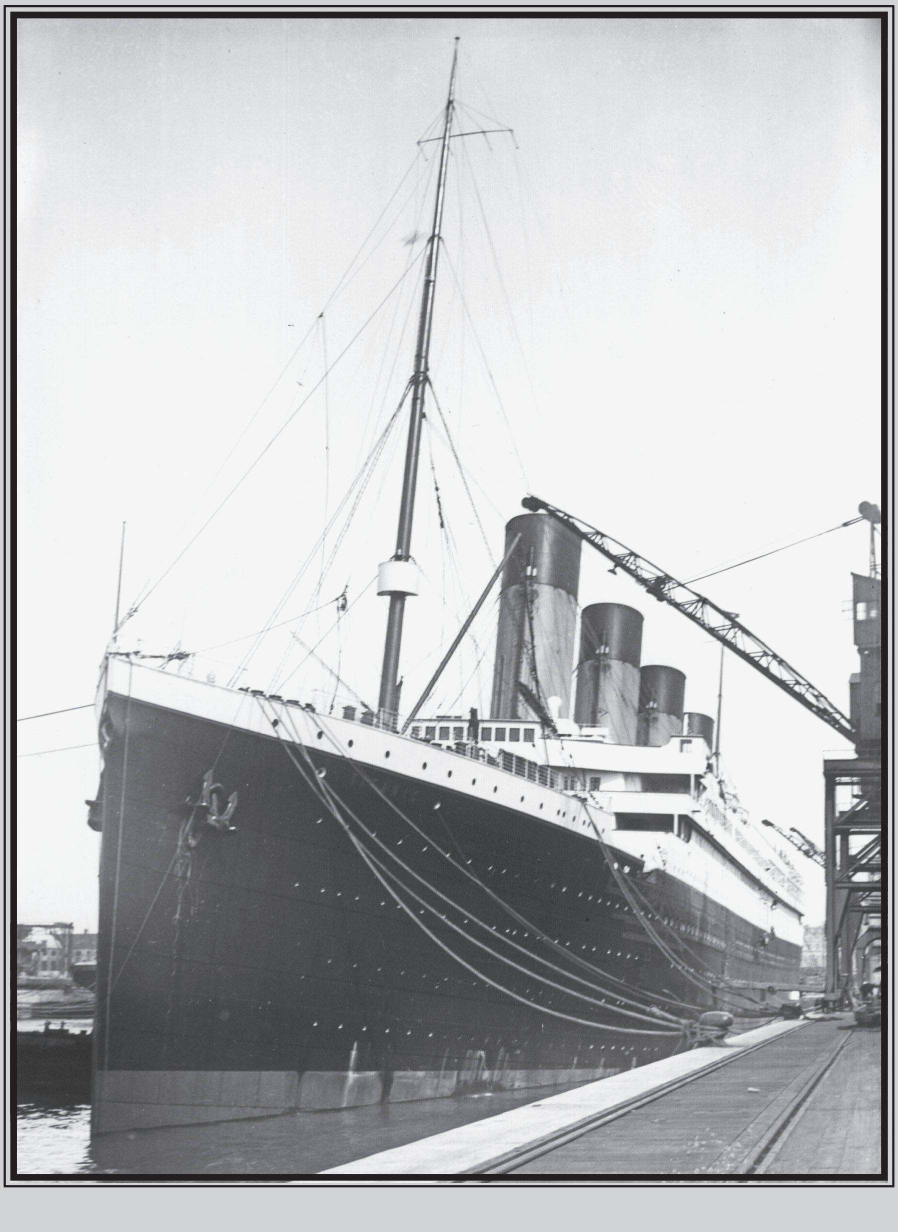


Fig. XXIX A strangely deserted White Star dock on the early morning of April 9.

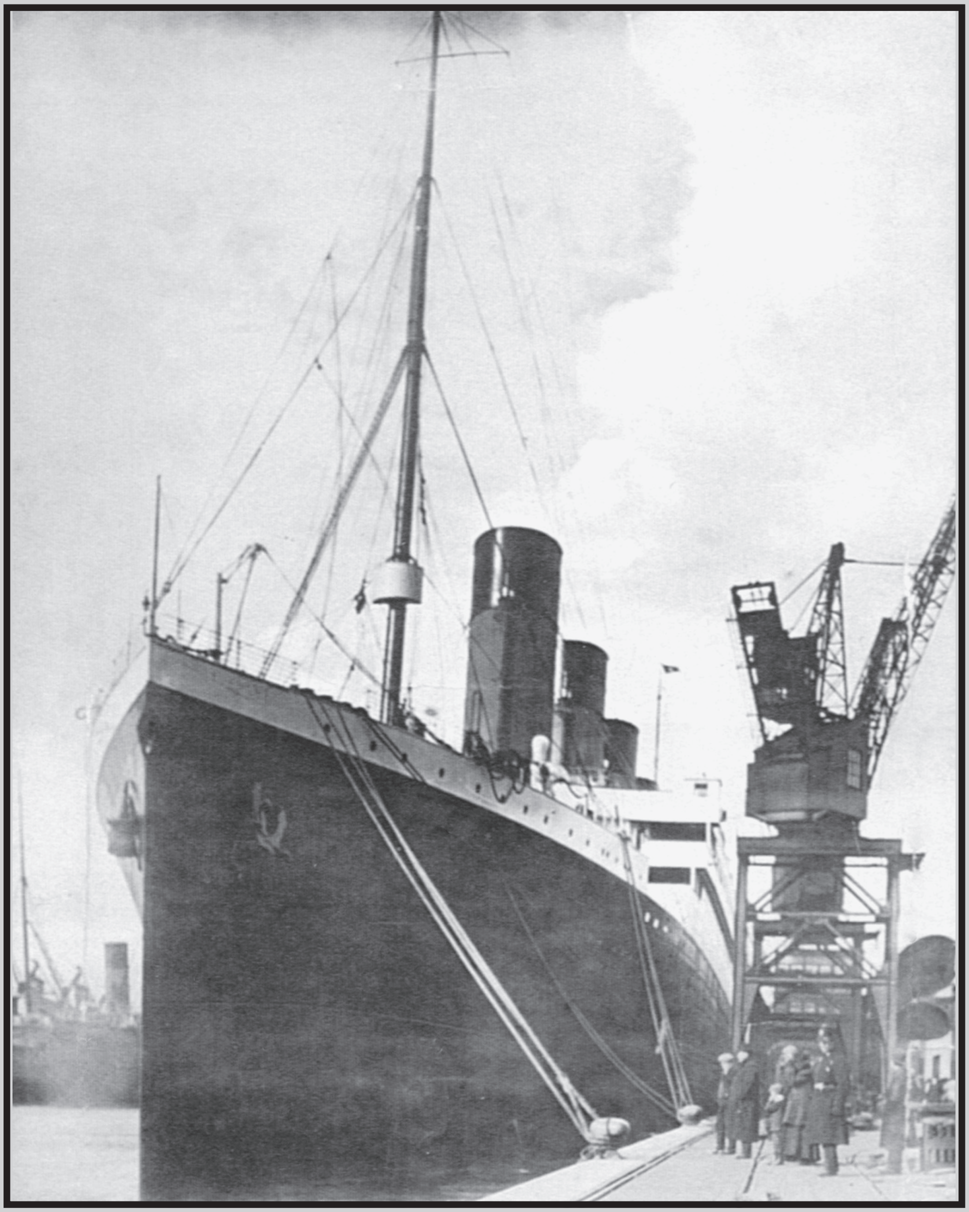


Fig. xxx A rare photograph of *Titanic*, taken April 9. Note the propeller blades behind the dockside crane. Because of the change in tidal level and the cranes having shifted their positions, the ship appears to have moved from its position in the preceeding photograph, but this is an illusion. *(R. Terrell–Wright collection)*

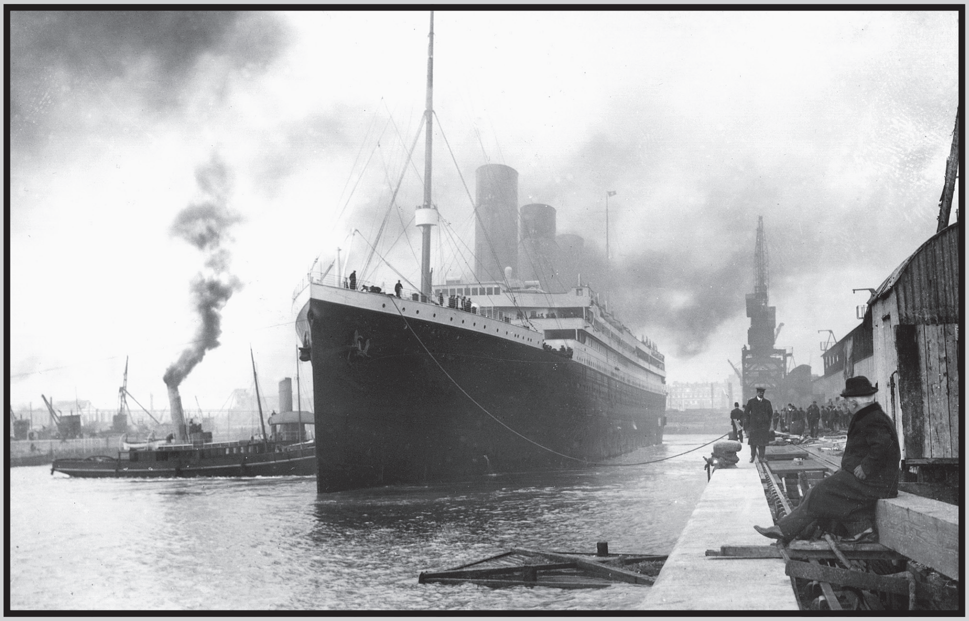


Fig. xxxi Just after noon, April 10, the last of the mooring lines are released. It is believed that the man sitting in the foreground is White Star Marine Superintendent Captain Benjamin Steel.

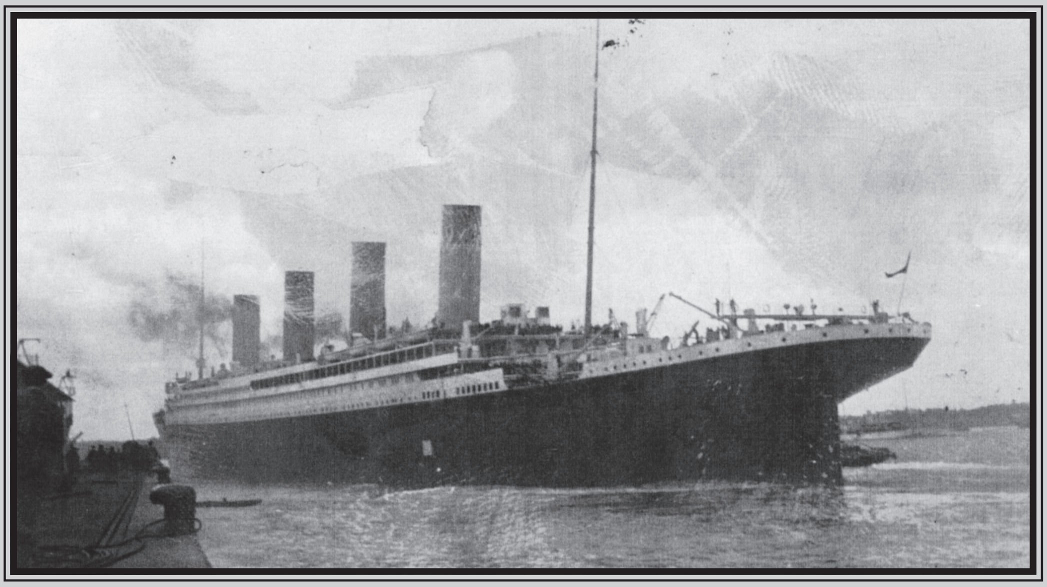


Fig. xxxii
Titanic leaving Southampton (1). *(R. Terrell–Wright collection)*

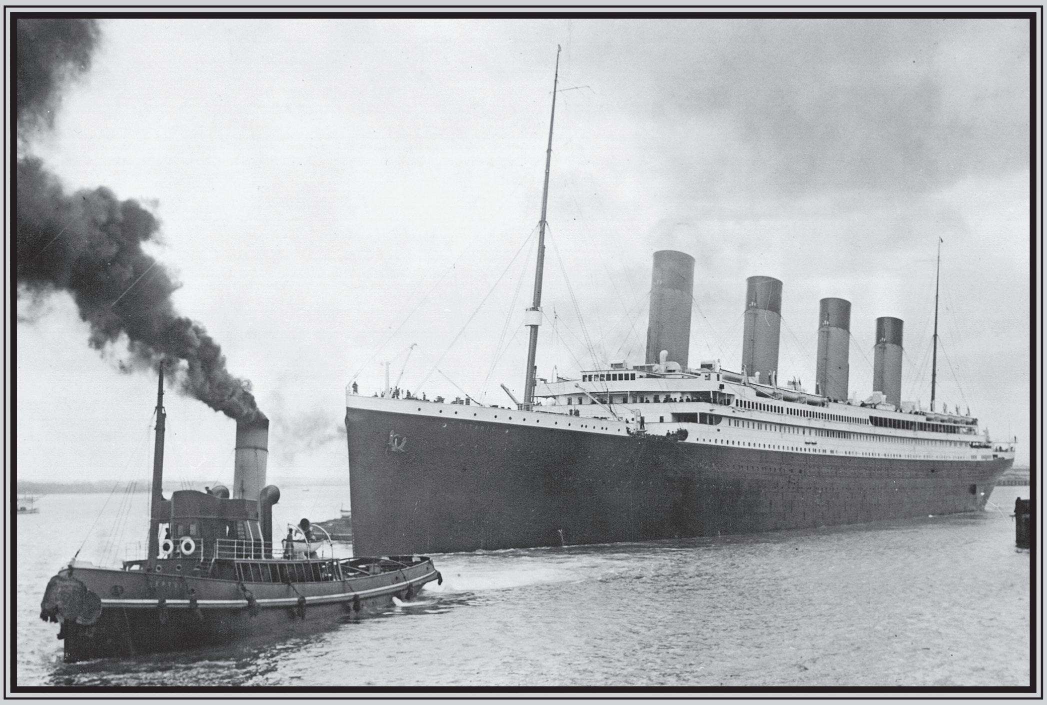


Fig. xxxiii
Titanic leaving Southampton (2).

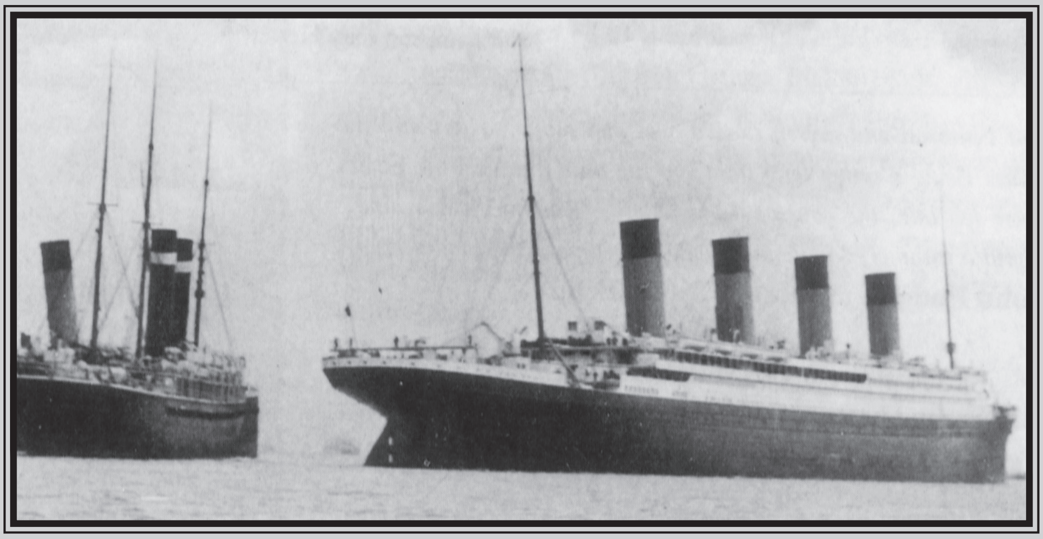


Fig. xxxiv
Titanic leaving Southampton (3). *(R. Terrell–Wright collection)*

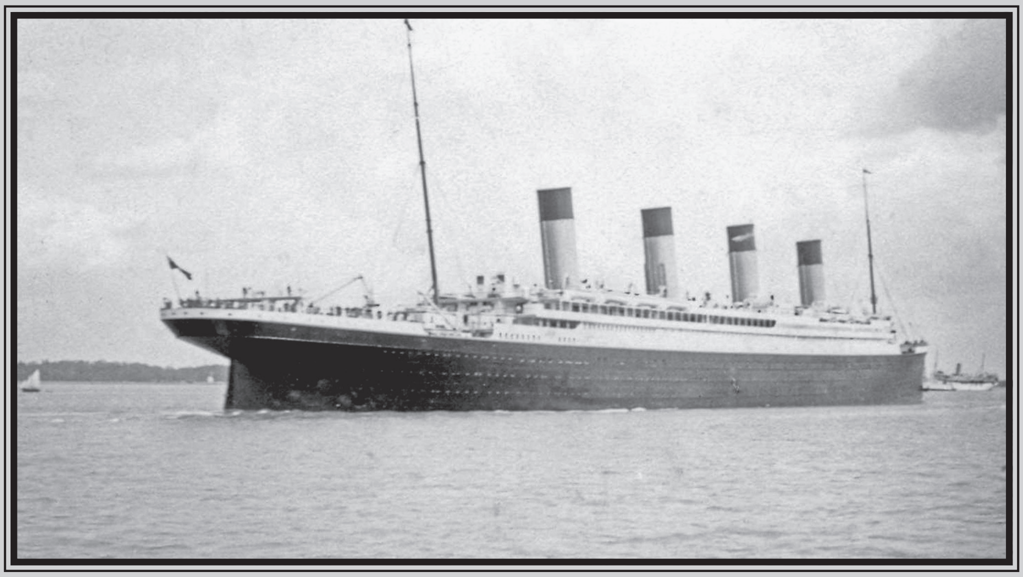


Fig. xxxv
Titanic leaving
Southampton (4).
*(R. Terrell–Wright
collection)*

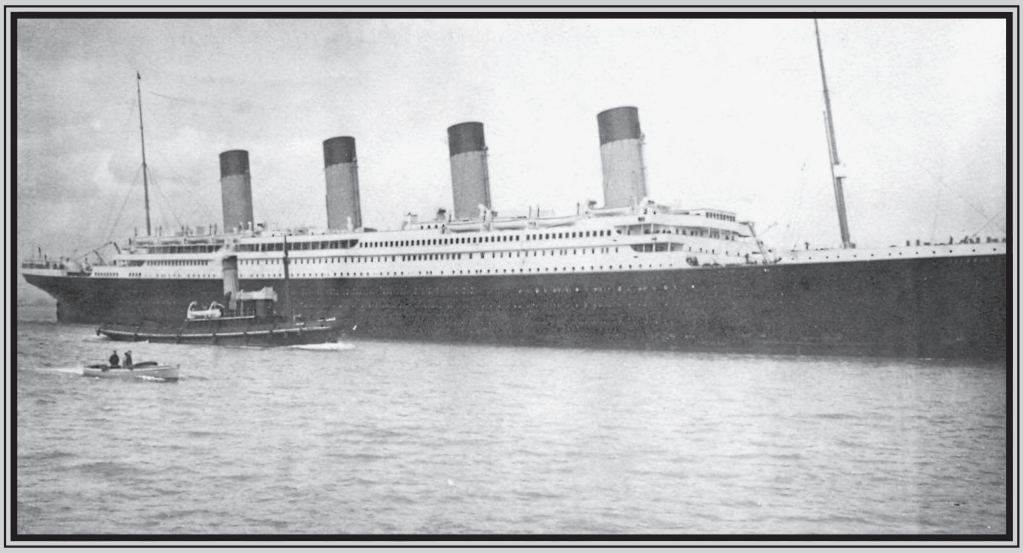


Fig. xxxvi
Titanic leaving
Southampton (5).
*(R. Terrell–Wright
collection)*

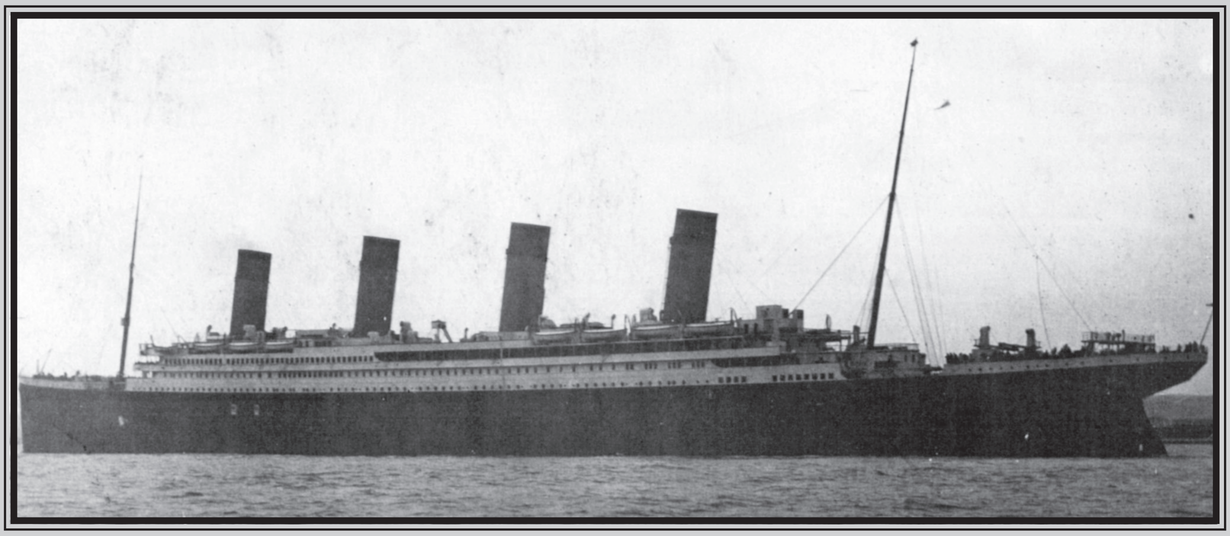


Fig. xxxvii *Titanic* at Cherbourg. *(R. Terrell–Wright collection)*

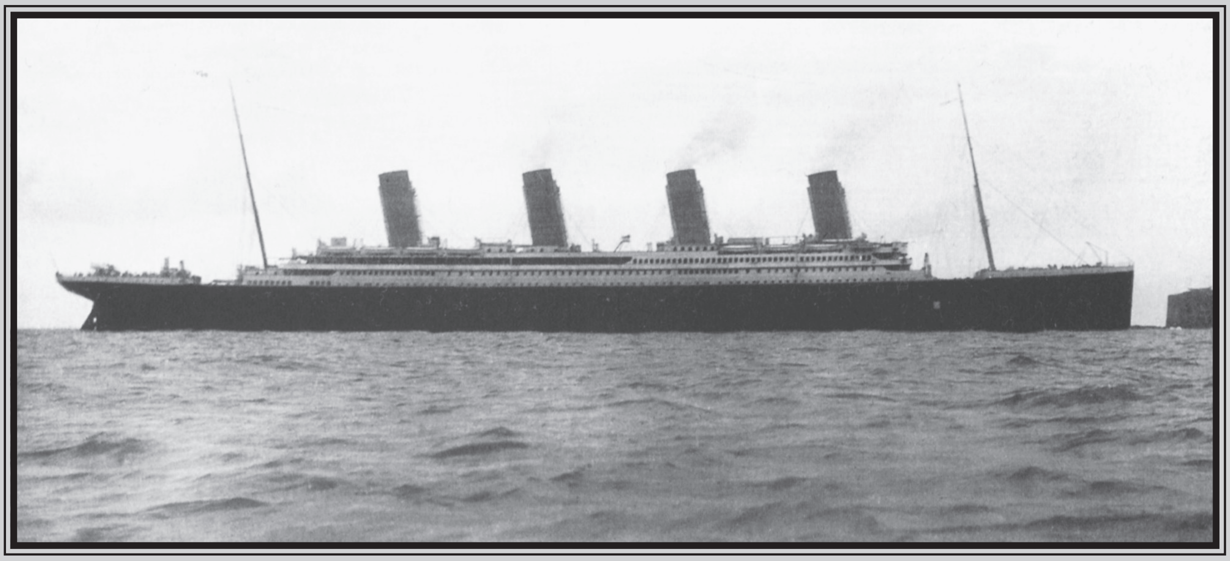


Fig. xxxviii *Titanic at Cherbourg. (R. Terrell–Wright collection)*

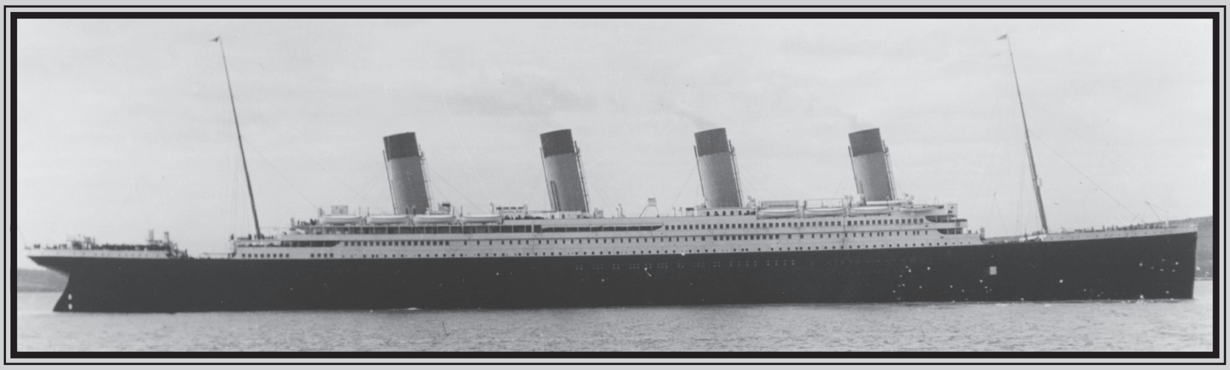


Fig. xxxix *Titanic* entering the harbor at Queenstown. The white square appearing on the hull is the open E Deck door. *(Cork Examiner photograph – authors' collection)*

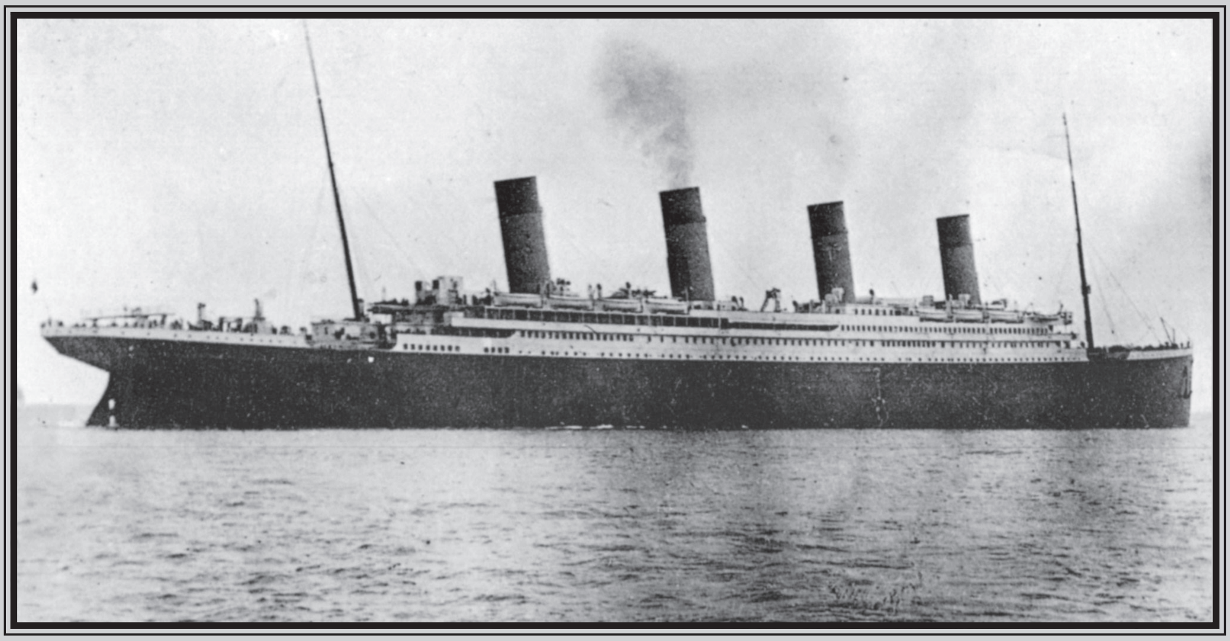


Fig. xl *Titanic* is soon to sail into history. She is seen here in a photo taken from a tender by a passenger leaving the ship at Queenstown. *(Father Browne photograph – authors' collection*)

Chapter 1

Inception and Construction Plans

The time of *Titanic* could well be called the era of the Atlantic giants. Between 1901 and 1910, over eight million European emigrants landed at New York, with nearly two million of those coming from Northern and Western Europe. In competing for this transatlantic trade, steamship companies commissioned ever larger and faster ships from their builders. Ships that were described in superlatives at the time of their launch were soon outclassed by even grander vessels. The White Star Line's *Oceanic*, at 17,274GRT (gross registered tonnage), was intended to be the largest and most luxurious ship of the nineteenth century when she was launched in January of 1899. Yet over the next eight years, this record was eclipsed no less than six times, culminating in the Cunard Line's *Lusitania* and *Mauretania*. At 31,550 and 31,938GRT respectively, these ships were intended to secure Cunard's pre-eminence on the North Atlantic, as larger, faster and safer ships also meant increasingly attractive passage for first- and second-class passengers.

By this period in time, several British firms had become world leaders in shipbuilding. Swan, Hunter & Wigham Richardson Ltd of Wallsend on Tyne, for example, was the builder of *Mauretania* and a significant number of other ships of the Cunard fleet. Another of Cunard's preferred builders, John Brown & Co., of Clydebank, built *Lusitania*. Harland and Wolff, of Belfast, enjoyed a particularly close association with the White Star Line, being the exclusive builder for ships launched under the White Star name. *Titanic*'s launch in 1911 gave Harland & Wolff the distinction of having produced a greater aggregate tonnage in one year than any other shipyard in the world. But what made Harland and Wolff stand apart from most yards was the fact that it was equipped to completely design, build and launch a ship – hull, machinery, interiors, furnishings – all at its own works. Thus, when White Star decided to build the *Olympic*-class ships, it had full confidence that Harland & Wolff could deliver.

The shipbuilding firm that would later be known as Harland & Wolff was started by Edward J. Harland in 1859 when he acquired the shipyard of his former employer, Robert Hickson & Co. He was joined by Gustav W. Wolff in 1861, and in January of 1862 the company's name was officially changed to 'Harland & Wolff' to reflect the new partnership. In 1874, three others were taken into the partnership – Messrs. William J. Pirrie, Walter H. Wilson and Alexander B. Wilson. Alexander Wilson retired shortly after joining the firm; Sir Edward Harland died in 1895, and Gustav Wolff retired from the firm in 1903 after selling his shares in the partnership to Pirrie. With the death of Walter Wilson in 1904, William J. Pirrie – known as Lord Pirrie after being elevated to the peerage in 1906 – remained as the Chairman and sole principle in the business. Under Lord Pirrie, there were six Managing Directors, each being responsible for the day-to-day operations of one particular department. These directors were the Right Honorable Alexander M. Carlisle, Chairman of the Managing Directors and Chief Naval Architect; W. J. Pratten, Consulting Engineer (Pratten had only just retired as Manager of the Engine Works); John W. Kempster, Manager of the Electrical Department; Thomas Andrews, head of the Design Department; George Cuming, Engine Works Manager; and Robert Crighton, Manager of the Harland & Wolff works at Southampton. Naval Architect Edward Wilding, who was responsible for all critical design calculations, reported directly to Thomas Andrews. Wilding would eventually become head of the Design Department after Andrews' death on the *Titanic*.

PLANS AND DRAWINGS

Titanic conceived

The order to proceed with the design of both of White Star's new mammoth liners was signed April 30, 1907, and the shipyard was given orders to proceed with construction of *Olympic* (yard number 400) and *Titanic* (yard number 401) on September 17, 1908.[1] As ship names were only used officially by the builder after the ships were launched, most plans and specifications provided for the construction were titled by yard numbers only. Since the first two of the three planned *Olympic*-class ships would be built simultaneously, they would share many of the same construction plans. As construction progressed on *Olympic*, any changes decided upon for *Titanic* were indicated by notes written on the plans, indicating the hull number to which they applied; in instances where the differences were considerable, separate drawings were made for *Titanic*.

The *Olympic*-class ships were intended to completely eclipse the Cunard Line's *Mauretania* and *Lusitania* in both luxury and size. To design and build a trio of ships of such unprecedented scale was no small task. However, Harland & Wolff had in place both the technical expertise and the shipbuilding facilities to handle just such a project. By 1912, Harland & Wolff Ltd was a full-service company employing some 14,000 men including both subcontractors and 'on-site' personnel. Approximately 6,000 of those were involved with the building of *Olympic* and *Titanic*, with approximately 1,000 working on the night shift.[2] The Belfast facility at Queen's Island contained no less than eight building slips, all capable of accommodating large vessels. However, due to the enormous size of the two new vessels, the slips in which *Olympic* and *Titanic* were built – Slips 2 and 3 – were constructed on an area previously occupied by three slips.

The following is a list of the main particulars for *Titanic*, submitted by Harland & Wolff for approval by the Board of Trade:

Hull number	401
Registration number	131,428
Length overall	882ft 9in
Length between perpendiculars	850ft 0in
Breadth extreme	92ft 6in
Depth molded to Shelter Deck	64ft 3in
Depth molded to Bridge Deck	73ft 3in
Total height from keel to Navigating Bridge	104ft 0in
Sheer forward	About 12ft 0in
Sheer aft	About 4ft 0in
Camber	3in, each deck for full width
Load draft	34ft 6in; 34ft 7in upon completion

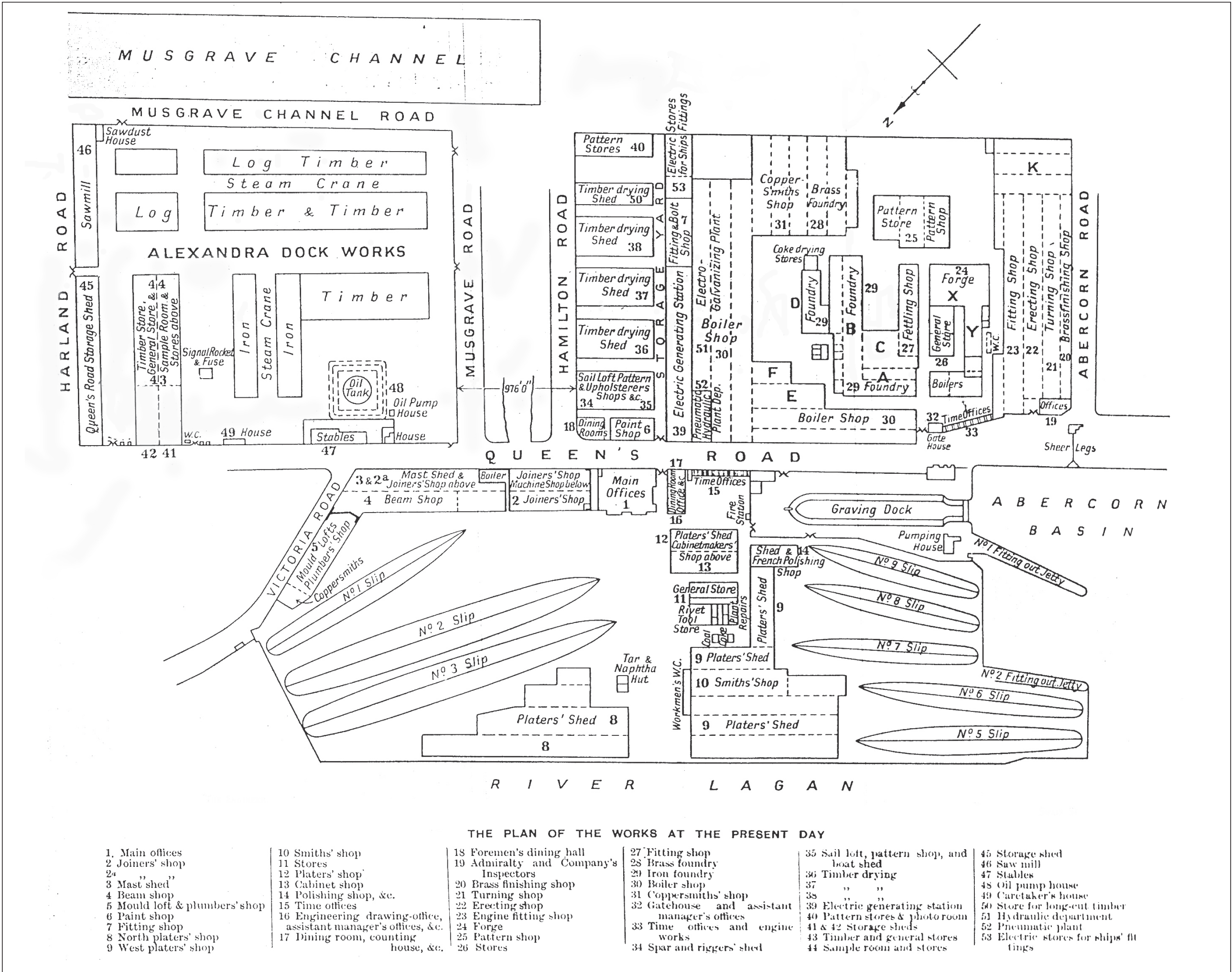

MUSGRAVE CHANNEL
MUSGRAVE CHANNEL ROAD
ALEXANDRA DOCK WORKS
HARLAND ROAD
MUSGRAVE ROAD
HAMILTON ROAD
STORAGE YARD
ABERCORN ROAD
QUEEN'S ROAD
VICTORIA ROAD
ABERCORN BASIN
RIVER LAGAN
Graving Dock
Pumping House
No 1 Fitting out Jetty
No 2 Fitting out Jetty
No 1 Slip
No 2 Slip
No 3 Slip
No 5 Slip
No 6 Slip
No 7 Slip
No 8 Slip
No 9 Slip
Main Offices
Boiler Shop
Foundry
Forge
Sheer Legs
Gate House
N
THE PLAN OF THE WORKS AT THE PRESENT DAY
1. Main offices
2 Joiners' shop
2a ,, ,,
3 Mast shed
4 Beam shop
5 Mould loft & plumbers' shop
6 Paint shop
7 Fitting shop
8 North platers' shop
9 West platers' shop
10 Smiths' shop
11 Stores
12 Platers' shop
13 Cabinet shop
14 Polishing shop, &c.
15 Time offices
16 Engineering drawing-office, assistant manager's offices, &c.
17 Dining room, counting house, &c.
18 Foremen's dining hall
19 Admiralty and Company's Inspectors
20 Brass finishing shop
21 Turning shop
22 Erecting shop
23 Engine fitting shop
24 Forge
25 Pattern shop
26 Stores
27 Fitting shop
28 Brass foundry
29 Iron foundry
30 Boiler shop
31 Coppersmiths' shop
32 Gatehouse and assistant manager's offices
33 Time offices and engine works
34 Spar and riggers' shed
35 Sail loft, pattern shop, and boat shed
36 Timber drying
37 ,, ,,
38 ,, ,,
39 Electric generating station
40 Pattern stores & photo room
41 & 42 Storage sheds
43 Timber and general stores
44 Sample room and stores
45 Storage shed
46 Saw mill
47 Stables
48 Oil pump house
49 Caretaker's house
50 Store for long-cut timber
51 Hydraulic department
52 Pneumatic plant
53 Electric stores for ships' fittings

Fig. 1-1 **H&W Works Map** – The Harland & Wolff works as it appeared in 1909. *(*The Engineer*/Authors' collection)*

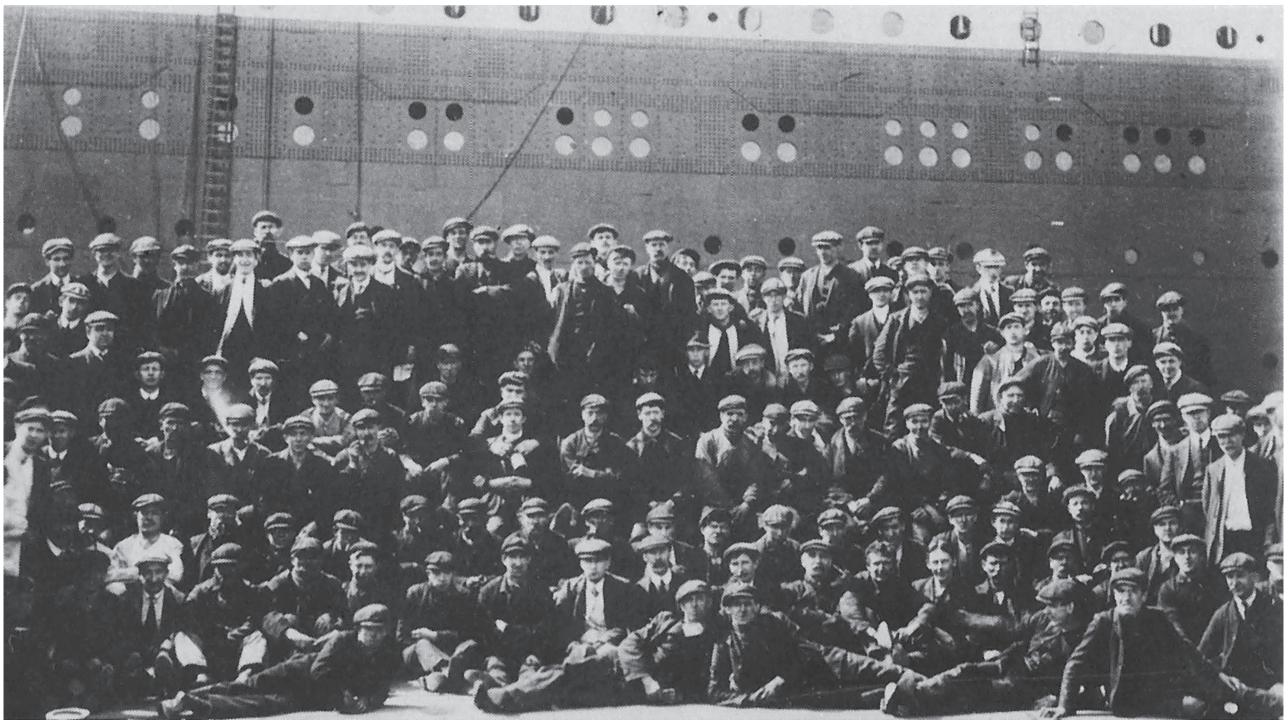


Fig. 1-2 **Workmen in front of *Olympic*** – Harland & Wolff employees proudly pose in front of their latest creation shortly before her completion. This image from a period postcard, though labeled as *Titanic*, is actually *Olympic*. *(Ray Lepien Collection)*

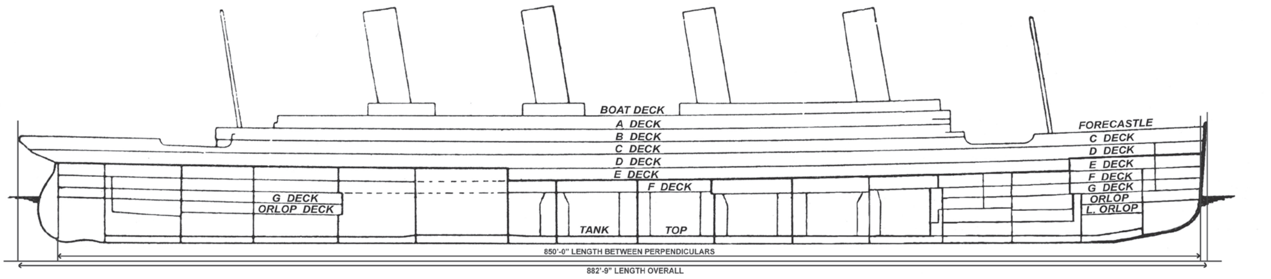


Fig. 1-3 **Length of Ship** – Illustration showing the points at which the Length Between Perpendiculars and Length Over All were measured.

Displacement at load draft	52,310 tons
Gross tonnage	46,328.54
Net register tons	21,831.34
Indicated horsepower of reciprocating engines	30,000
Shaft horsepower of turbine engine	16,000

As with earlier White Star Liners, the *Olympic*-class ships were designed with a 'schooner' rig,[3] straight stem and a graceful, elliptical counter stern. Unlike the ships which preceded them, the three sisters would have four funnels and two masts. The *Titanic* was classed by the Board of Trade as a 'shelter deck vessel' and was built to adhere to the regulations for both passenger and emigrant ships.

There were eight passenger decks on *Olympic* and *Titanic* – the Boat Deck, Promenade Deck (A), Bridge Deck (B), Shelter Deck (C), Saloon Deck (D), Upper Deck (E), Middle Deck (F), and Lower Deck (G) – while at each end of the ship there was a partial deck known as the Orlop Deck. The after end of the Orlop Deck aft of WTB (Watertight Bulkhead) 'O' and immediately above the after shaft tunnels was also referred to on the main structural drawings as the 'Tunnel Deck'. This portion of the deck was designed to create a watertight flat above the after shaft tunnel in order prevent flooding of the hold above in the event of a complete failure of any of the tailshafts or stern tubes. There was also an additional deck located forward within the No.1 Hold, called the Lower Orlop Deck. At the very lowest level within the ship, the top plating of the double bottom was called the 'Tank Top'. These last three levels were not considered decks in the formal sense of the term, and in many publications dealing with the *Olympic*-class ships are often omitted when the various decks are described. This meant that although *Titanic* had eight 'passenger' decks, there were actually eleven deck levels in total, not counting certain areas of the superstructure referred to by some seamen as 'sun decks' and 'fidley decks'.

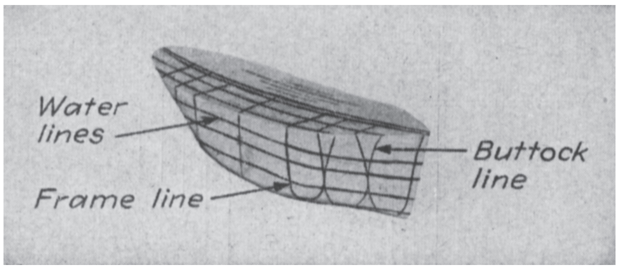


Fig. 1-4 **Intact Model** – An intact model showing water lines, buttock lines, and frame lines drawn onto the outside where they intersect the shell.

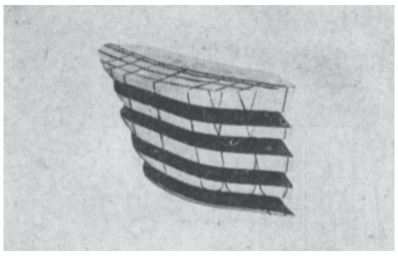


Fig. 1-5 **Water Planes** – The model cut parallel to the base line and lifted vertically to show the shape of the water lines.

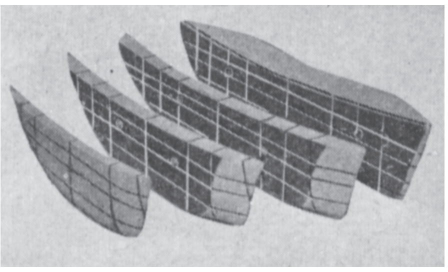


Fig. 1-6 **Buttocks** – The model cut vertically, parallel to the centerline plane and pulled apart laterally, to show the shape of the buttock planes.

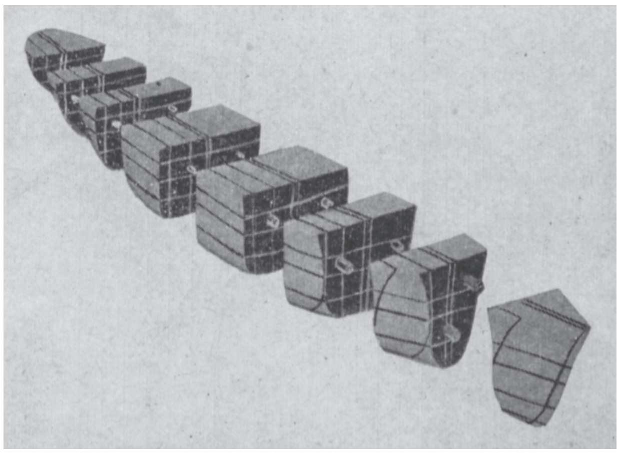


Fig. 1-7 **Frame Lines** – The model cut at transverse intervals to show the shape of the frame lines.

Preparation of drawings

The form of any solid body such as a ship can be determined by cutting it into sections and then noting its shape as revealed by the outlines of the cut surfaces. In the early days of shipbuilding, and even as late as the era of the great clipper ships, the naval architect would make a scale model of a proposed ship and lift lines from this model. The model was usually built of horizontal planks in sandwich fashion. The temporarily attached planks would then be shaved here and there until the experienced model builder was satisfied that a good, fair form had been obtained. The planks of the model were then separated, and measurements, or offsets, were taken from the model at different plank levels. These offsets were then used to lay out the frames, planking, etc., of the full-sized ship.

The Lines plan

An actual ship cannot be sawn apart and measured, but its form can be defined in much the same way as that of the model by passing three sets of theoretical parallel planes through its hull. By combining the curves generated at these intersections, a drawing can then be prepared that defines the form of the ship.

The planes of one of these three sets are horizontal, or parallel to the base; the curves created by their intersections with the molded form are known as 'water lines'. The water-line planes correspond to the upper and lower surfaces of the planks composing the designer's wooden model. In making the model, alternate planks of light and dark wood were sometimes used, or the planks were assembled with dark glue, creating visible intersections to show the water line shapes more distinctly.

The second set of planes was vertical and ran longitudinally or parallel to the fore-and-aft centerline; the curves created at their intersections with the molded hull surface were called 'buttock lines'. If the designer's model was built up out of longitudinal planks set on edge instead of being laid flat, the surface of these planks would correspond to the buttock planes.

The third set of planes was also vertical, but ran transversely or perpendicular to the fore-and-aft centerline. The surface intersections of these planes were parallel to the frame lines and correspond to the surfaces of the transverse vertical planks that were sometimes used instead of horizontal planks in making the models.

For the purpose of showing the relationship of the three sets of intersection curves to one another, a drawing called the 'Lines plan' was made. The Lines plan showed the outlines of all the cross-sectional planes required to define the molded surface of the hull, as well as intersections created at the various decks. The molded surface of the hull was bounded at the top by the sheer (the fore-and-aft rise of the upper edge of the hull) and at the ends by the stem and stern profiles. All other lines shown on this plan represented the intersections of the three aforementioned sets of parallel planes with the molded form of the ship or, in other words, the traces of these planes on the molded surface of the hull.

The Lines plan consisted of three principal views of the ship's form. These were known as the 'Half-Breadth' plan, the 'Profile' or 'Sheer' plan, and the 'Body' plan. These three views showed the ship's form as it appeared from above, from the side and from the ends, respectively. In each view, the molded surface intersections of one of the three sets of planes, being seen in outline, appeared as curves, while the other two sets of planes, being seen edgewise, appeared only as straight lines. All three views were laid out from two fore-and-aft reference planes, one horizontal through the base of the molded form and the other vertical and longitudinal through its center. The intersection of the horizontal reference plane with any view was called the 'base line' and the similar intersection of the vertical reference plane was called the 'center line'. The fact that these lines represented planes viewed edgewise explains why the base line ran longitudinally on the profile and transversely on the body plan, while the center line was vertical on the body plan and horizontal on the Half-Breadth plan.

Specifically, these plans were drawn as follows:

1. Half-Breadth plan

The Half-Breadth plan was usually drawn for the port side only, as a ship's hull is generally symmetrical about the center line. The Half-Breadth plan looked down on the ship, showing the hull cut horizontally by the first set of planes which were parallel to the base. The curved outlines of these planes were the water lines which revealed the form of the hull at various heights above the base. The Half-Breadth plan also gave the location and spacing of the frame stations and buttock planes, both appearing edgewise as straight lines. The decks, bulwark rail and stern knuckle, if any, also appeared as curves in this view.

2. Profile plan

The Profile plan was the longitudinal side elevation, generally drawn with the bow to the right. It showed the contour of stem and stern and the sheer of the decks, rail and knuckle. Its main purpose was to show the molded form of the ship at the centerline and at the longitudinal vertical planes called 'buttocks', parallel to the fore-and-aft center line. It also showed the location of frame stations and water-line planes, which were both seen edgewise as straight lines in this view; the sheer lines of the decks, rail and knuckle were curved.

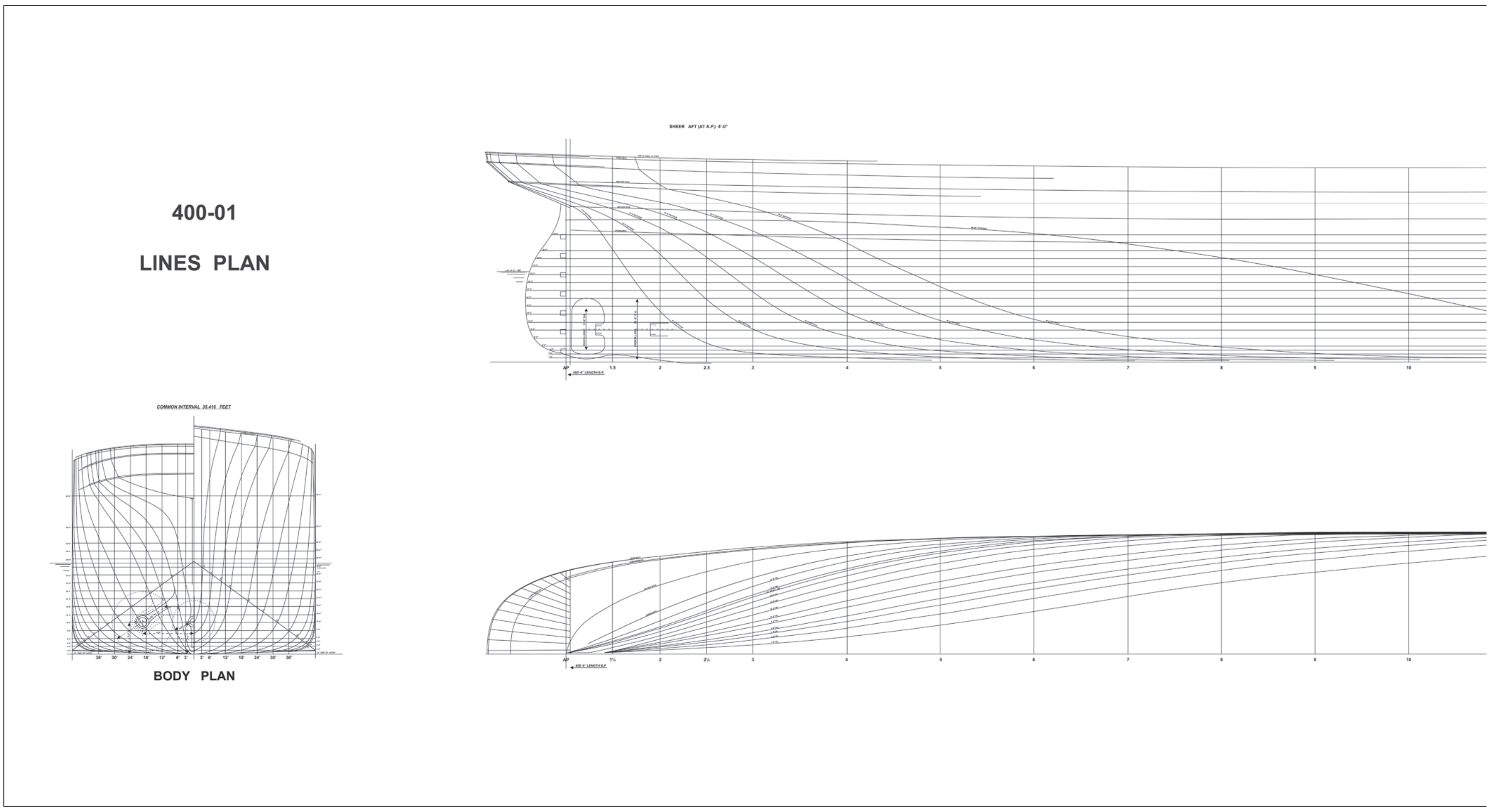
3. Body plan

The Body plan was an end-wise view of the ship's molded form showing its shape at each transverse frame-station plane. It also located the decks, rail, knuckle, longitudinal girders, sight edges of shell plating and the frame endings. All these lines appeared as fair curves in this view, while the water lines and buttock planes were shown as straight lines. As in the case of the Half-Breadth plan, and for the same reason, the Body plan was drawn for one side of the ship only. The sections forward of amidships, making up the 'forebody', were shown to the right of the centerline, while the sections aft of amidships, in the 'afterbody', were shown to the left.

Additional planes, known as 'diagonals', were also used to define the longitudinal molded form through the turn of the bilge and just above and below it. These planes ran diagonally downward from the centerline toward the bilge, more or less normal (perpendicular) to the molded hull surface. They were seen edgewise as straight lines in the Body plan, but their true form did not appear in either of the other two views of the lines plan and were usually shown in a separate view, often combined with the Half-Breadth plan.

Fairing

When a line or surface flows in an easy and smooth curve with no undue high spots or hollows, it is said to be 'fair'. In the parlance of the draftsman or loftsman, the art of producing curves and surfaces that meet these criteria is called 'fairing'. The intent in fairing the lines is twofold. The first, as the name suggests, is to ensure that the surface of the vessel is perfectly fair; the second is to obtain complete agreement between the Body, Sheer and Half-Breadth plans. The fairing process consists basically of drawing new curved lines in the Half-Breadth plan by using measurements obtained from the Sheer and Body plans, and then drawing a new Body plan to full or enlarged scale by using measurements obtained from the Sheer and Half-Breadth plans. Similarly, lines that appear curved in the Sheer plan are drawn to full or



enlarged scale by using measurements obtained from the Half-Breadth and Body plans. These processes are repeated until the three plans contain perfectly fair lines in complete agreement with each other.

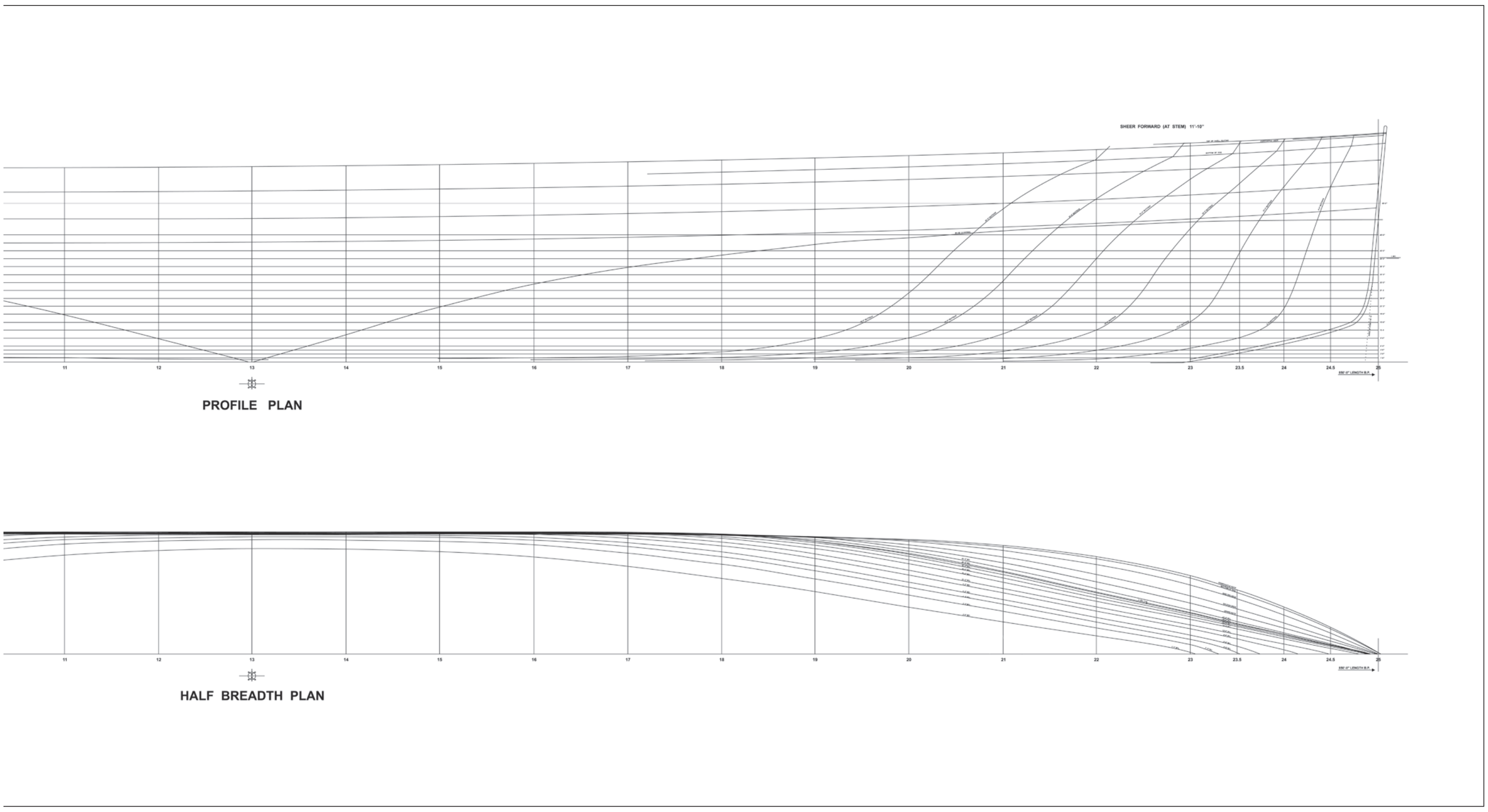
Offsets

The curved lines of a ship's molded form, which have no fixed shape that can be conveniently dimensioned in a direct way, must instead be dimensioned at regular intervals along the constantly changing curves. The measured dimensions to the outlines of the ship's molded form are known as 'offsets'. This name is derived from the fact that these outlines can be reproduced, either full-size or scaled-down, by 'setting off' these dimensions from the base line, center line, or any other fixed reference line. When set off vertically above the base, an offset is called a 'height'. When set off horizontally from the centerline, it is a 'half-breadth' or 'half-width'.

When three planes intersect each other at right angles, as the various planes on the lines plan do, any point in the line of intersection between two of these planes can be precisely located by a single dimension, measured from the third plane along this intersection line. This principle is followed in measuring the offsets for a ship's molded form, which are generally taken at each frame station, as half-widths to each water line or as heights to each buttock line. Since the offset is measured along the intersection of the frame-station plane with the water line or buttock plane for which it is given, only this one dimension or offset is required to locate each point in the sectional outlines of the molded form. The traditional manner in which the offsets were recorded was in feet, inches and eighths of an inch, using only whole numbers to represent each. For example, an offset measurement recorded as '8-10-4' represents a measurement of 8ft 10½in, while an offset recorded as '0-9-6' represents a measurement of 9¾in.

Preliminary lines

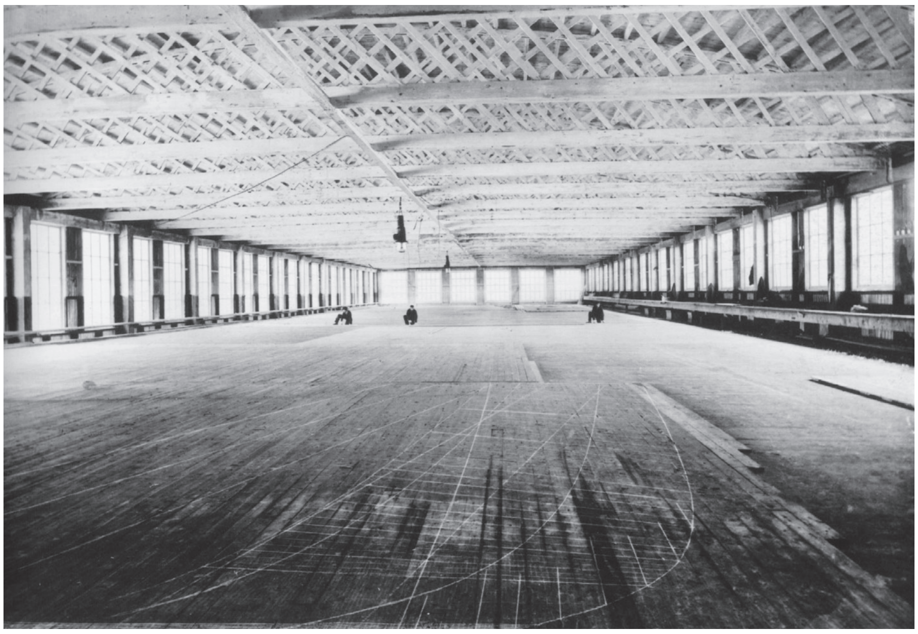
The lines of a new ship, as determined by its designer, were first drawn and the initial fairing of the ship's lines completed at a reduced scale (usually 1/48) by the drawing office of the shipyard. The resulting drawing was called the 'Preliminary Lines plan'. On the Preliminary Lines plan, the transverse sections were drawn not at frames, but at 'stations' equally spaced between the forward and after perpendiculars of the ship. These stations divided the length of the vessel into an even number of intervals for convenience in calculating displacement. Another reason for drawing the preliminary lines at displacement stations was that exact frame spacing was usually not determined until long after these lines had been drawn. From the preliminary lines, measurements taken with a scale were made up into a table known



as the 'preliminary offsets'. This table, along with the Preliminary Lines plan, was then sent to the Mold Loft for laying off and final fairing at full size.

The Mold Loft

As stated previously, the initial fairing of the lines was done by the draftsman during the laying-out of the Preliminary Lines plan. Upon completion, the preliminary lines and offsets were then turned over to the loftsmen, whose domain was the Mold Loft. Harland & Wolff, as with other shipyards, had a special building constructed for the purpose of laying out the design of each ship before it was constructed. The Mold Loft was a large floor upon which the loftsmen chalked the lines of the cross-sections of a ship at full size, and the length at quarter scale. The work of the Mold Loft also included making templates, or 'molds', of heavy paper or thin wooden boards for all the structural parts



Above Fig. 1-8 **Lines Plan** – The 'Lines plan' – the collected water lines, buttocks and frame lines – for *Olympic* and *Titanic*. *(Illustration by Bruce Beveridge/Based on the original Lines Plan from Harland & Wolff)*

Right Fig. 1-9 **The Mold Loft** – (The Shipbuilder*/Authors' collection)* of the ship. A template for a steel plate consisted of a full-size pattern of the plate marked out and showing in detail all punched or countersunk holes, scarfs, bends and angle lines. The use of paper had disadvantages as the material would contract or expand with changes in humidity, sometimes necessitating multiple corrections on the ship. Templates of basswood or white pine were superior to paper and could be stored more easily.

The Mold Loft at Harland & Wolff occupied the upper floor of the Plumber's Shop and was over several hundred feet long and a hundred feet wide. There, the lines were carefully laid out, during which the loftsmen performed a thorough and more accurate fairing of the form. This was done to eliminate the small errors and inaccuracies inherent in the preliminary lines due to the small scale at which they were drawn on the plans. Once these corrections had been made, a final complete table of offsets was recorded and returned to the design department along with the lines plan for the draftsman to update.

After the vessel was laid off on the Mold Loft floor, the lines were transferred to the scrive board. The scrive board was a rectangular area large enough to take the full-sized midship section of the vessel, made up of stout planks 9 to 11in wide tightly clamped together. To this the loftsman first transferred the midship section of the vessel (to outside of frame) and then transferred every frame between the stem bar and sternpost. The loftsman then prepared supple pine battens which he bent around each frame on the scrive board, fixed by means of long steel pins alternately driven into the board on each side of the batten. He then cut or 'scrived' every frame into the scrive board with a sharp-edged tool called a scriving knife. He also scrived-in all decks, stringers, keelsons and floors. The shell plating seams or 'edge laps', also shown on the scrive board, were usually painted on in white.

Specifically, the scrive board illustrated the following features:

(a) The outer edges of the frame bars
(b) The inner edges and upper boundaries of floor plates
(c) The landing edges of the shell plates
(d) The lines of the upper parts of beams at the outer edges of the frames
(e) The middle lines of keelsons and side stringers
(f) The positions of ribbands for holding the frames in their proper places
(g) The numerous water lines by which the vessel was faired
(h) The bow and buttock lines employed for the same purpose

When the scrive board was completed, the planks making up the board were unclamped and carried to a location in the shipyard near where the frames and reverse frames were bent and the floor plates prepared. Here the scrive board was re-assembled and secured as before.

The scrive board did not show the structural arrangement of the frames, but merely their curvature and the position of each one of the shell landings, side stringers, keelsons, deck beams, floors, etc. This detailed information was supplied in a frame list and a plan of the midship section and profile. The frame list was a tabulated document fully describing the particulars of each and every frame. It took account of and indicated the following details:

(a) The scantlings of each frame, reverse bar, and floor.
(b) The height to which the reverse bars extended.
(c) Those frames which had to be cut at watertight deck flats, or at cargo ports, scuppers, etc., and those which had heel pieces at the center line, or were doubled at any parts, and to what extent.
(d) Those frames to which beams were attached, with the depth of the beam knees and the number and size of the connecting rivets.
(e) Those frames which were of web type and those to which watertight and other bulkheads were attached.
(f) Those frames whose shell flange was reversed for special reasons or whose floor plates were to be punched for intercostal plates.
(g) Those frames in the machinery space which had double reverse bars and in which special rivet holes were required for the attachment of the machinery seatings, boiler and shaft stools, etc.
(h) The type of connection to the margin plate, whether by single or double lugs or by gusset plates.
(i) The spacing and size of the rivets for each part of each frame, plus the spacing of the boltholes in the reverse bars for the ceiling, planking, and sparring.

Detailed sketches of the parts, with dimensions, were given with this information so that as each frame was prepared, the men could construct it exactly as required by noting its particulars on the list and in the Profile plan. This minimized the need for subsequent alterations involving considerable trouble and expense. It was the practice at H&W to also create a Framing Plan; this drawing showed all of the various frames of the hull in their pre-bent or 'developed' form, and gave the scantlings and length of each piece.

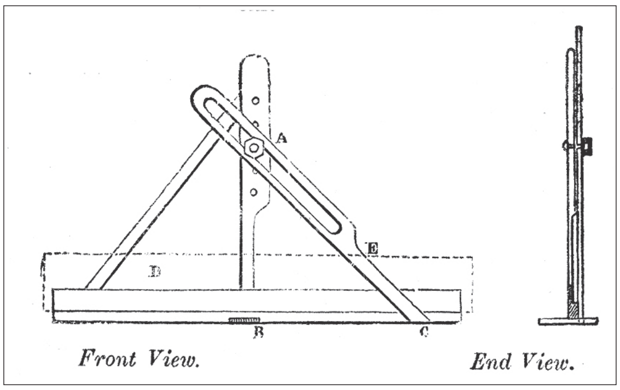


Fig. 1-10 **Beveling Instrument** – The beveling instrument consisted of a bevel, the tongue of which had a sliding joint, the stock of the bevel being also the tongue of a square. The stock of the square was laid upon the scrive board, with the beveling board D (indicated by dotted lines) resting upon it in the manner shown. The centerline of the tongue of the square was fixed at point B, where a beveling spot had been chosen upon a frame curve on the scrive board (usually at a ribband line), and the center line of the tongue of the bevel was placed at C, where a perpendicular from the frame at the point B on the scrive board cut the adjacent frame line. The pin A having been fixed as such a height that AB was the frame spacing of the vessel, it consequently followed that the line EC gave the beveling of the angle iron.

Beveling

Beveling boards were sometimes prepared to use when setting frames and reverse frames to the curves shown on the scrive boards. At some shipyards, workmen took the bevels directly from the board by use of an apparatus called a 'beveling instrument' consisting of a bevel, the tongue of which had a sliding joint, the stock of the bevel also being the tongue of a square.

To further instruct the workmen in the shops, plans of the decks, a sketch of the profile and other details of the construction were drawn on boards. These were protected from the effects of weather and frequent use by applying a coat of varnish. A tracing of the midship section on linen was often provided for the same purpose. These drawings illustrated only the steel and iron work of the hull proper, together with the decks; details for the guidance of the joiners and carpenters were furnished separately at a later stage.

Construction plans

After the overall dimensions and form of the ship had been settled and the preliminary design and general arrangement of the ship had been approved, several steps were required before actual construction could be undertaken. First, structural plans had to be prepared by the shipbuilder for submission to the Board of Trade for its approval. These plans consisted of general specifications of the hull, and the sizes or 'scantlings' of all steel, iron and wood forming the structural parts of the vessel. All of these features were to be distinctly marked according to the requirements of the Board of Trade. For *Olympic* and *Titanic*, among these plans were those for the construction of the watertight bulkheads, designed in accordance with the requirements specified in the latest report of the Board of Trade's Bulkhead Committee.

Titanic's plans were delivered for the Board's review on June 3, 1908. Once approved, they were returned to Harland & Wolff, which then proceeded to order the steel and iron. At that point, the draftsmen proceeded to prepare detailed structural plans for the workmen in the shipyard.

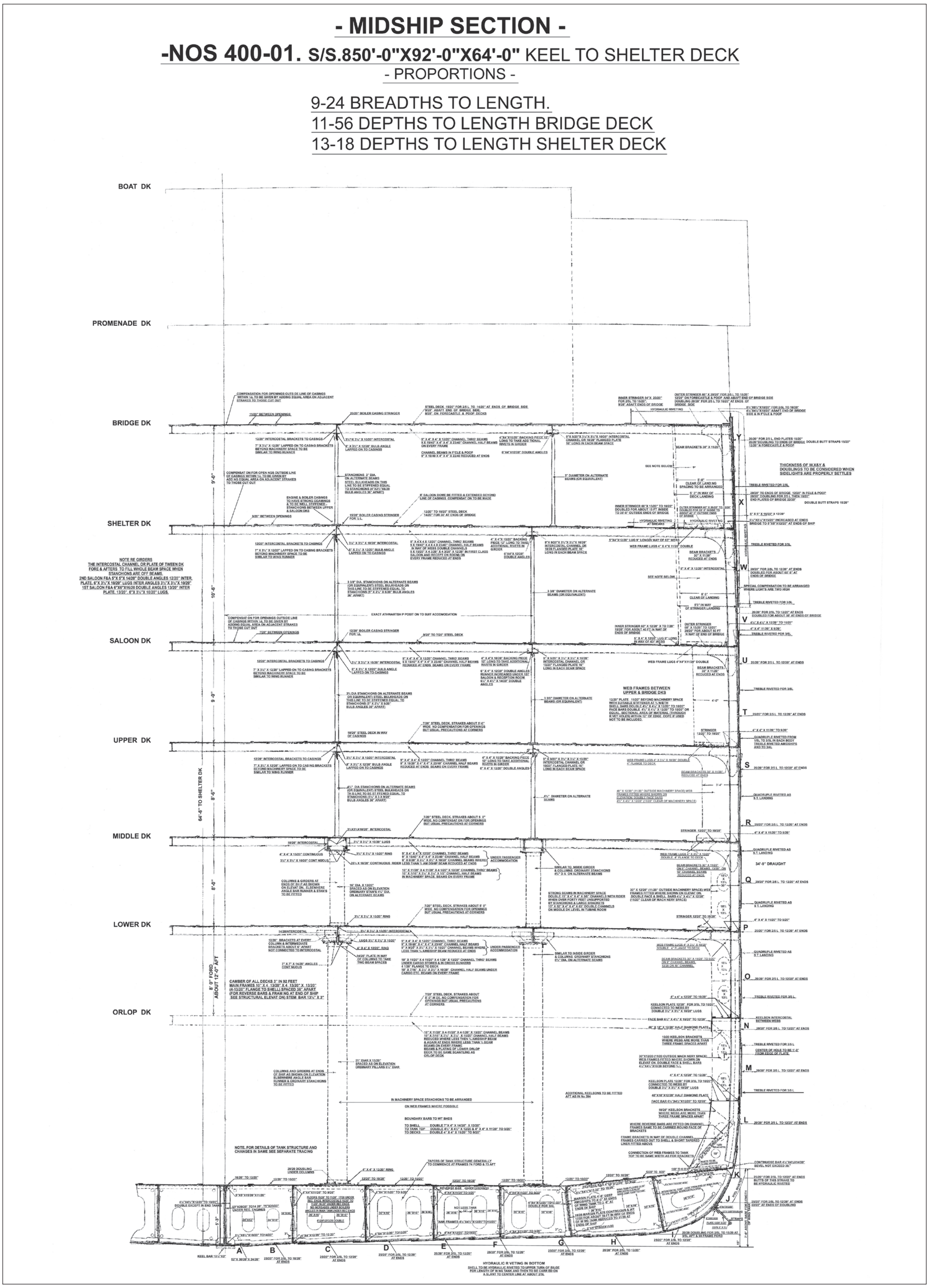
The initial drawings were comprised of:

(a) The midship section and any other transverse sections of the vessel that were needed to show the arrangement and sizes of the materials used in her construction. The midship section, the first detailed construction drawing to be made, not only indicated the cross form of the vessel's hull, but showed the general structural arrangement and the scantlings of the various parts. This was, in effect, an illustrated specification of the main structure of the hull.
(b) The 'inboard profile' or longitudinal vertical section of the ship showing the arrangement of decks, bulkheads, etc.
(c) The deck and hold plans.

Scantlings

The term 'scantlings' refers to the dimensions, or sizes, of the structural members used in the construction of a vessel. The sizes of plates, angle bars, etc., shown on the midship sections (and stated on the specifications of all vessels built in the British Isles) were, for the most part, fixed in accordance with the Rules of Lloyd's Register of British and Foreign Shipping. The scantlings of much of the tonnage built in foreign countries were also determined by these rules; about 70 per cent of the tonnage of iron and steel vessels built in Britain at the time were surveyed by Lloyd's Surveyors with a view to being classed in Lloyd's Register. The scantlings of remaining tonnage were very often impacted to a greater or lesser extent by the same rules.

Although the *Titanic* was not a Lloyd's-classified vessel, her scantlings generally exceeded the Lloyd's specifications, which did not yet cover ships over 680ft


- MIDSHIP SECTION -
-NOS 400-01. S/S.850'-0"X92'-0"X64'-0" KEEL TO SHELTER DECK
- PROPORTIONS -
9-24 BREADTHS TO LENGTH.
11-56 DEPTHS TO LENGTH BRIDGE DECK
13-18 DEPTHS TO LENGTH SHELTER DECK
BOAT DK
PROMENADE DK
BRIDGE DK
SHELTER DK
SALOON DK
UPPER DK
MIDDLE DK
LOWER DK
ORLOP DK
64'-6" TO SHELTER DK
9'-0"
10'-6"
9'-0"
8'-6"
8'-6"
8'-0" FORD ABOUT 12'-0" AFT
5'-3"
NOTE RE GIRDERS
CAMBER OF ALL DECKS 3" IN 92 FEET
NOTE. FOR DETAILS OF TANK STRUCTURE AND CHANGES IN SAME SEE SEPARATE TRACING
THICKNESS OF W,X&Y & DOUBLINGS TO BE CONSIDERED WHEN SIDELIGHTS ARE PROPERLY SETTLED
WEB FRAMES BETWEEN UPPER & BRIDGE DKS
34'-0" DRAUGHT
HYDRAULIC R VETING IN BOTTOM
A
B
C
D
E
F
G
H
J
K
L
M
N
O
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Q
R
S
T
U
V
W
X
Y

Fig. 1-11 **Midship Section** – The Midship Section plan of *Olympic* and *Titanic* based on the original Harland & Wolff preliminary plan for ship numbers 400-01 as submitted to the Board of Trade. The reader will note that certain features and specifications differ from the final approved design, such as the dome over the Dining Saloon. Because this drawing was intended as a reference for scantlings, it is not a true midship section. Note that the bottom half of the drawing shows Engine Room columns and hold columns rather than Boiler Room stanchions, etc. *(Illustration by Bruce Beveridge based on original H&W Midship Section plan)*

in length. The whole of *Titanic*'s scantlings conformed to the strict requirements of the British Board of Trade, requirements in which the designers at Harland & Wolff were well-versed. Belfast surveyors from the Board of Trade made over 2,000 inspection visits to *Titanic* during her construction, an average of two visits per day for every day of the three years she was under construction.

In order to regulate and graduate the scantlings and arrangements considered suitable for vessels of different dimensions, the Board of Trade had adopted scantling numbers. Scantling numbers, which were arrived at through the use of the equations that follow, corresponded to tabulated lists of the minimum sizes of the various materials and structural members permitted to be used in a given vessel. To obtain these numbers, the first step was to measure the length of the vessel and the breadth and depth of her midship frame section as follows:

Length Between Perpendiculars (L): In vessels where the stem formed a cutwater, as on *Titanic*, the length was measured from the fore side of the stem bar at the Upper Deck (E Deck in *Titanic*'s case) to the aft side of the sternpost – the 'Length Between Perpendiculars, Extreme'. 'Lloyd's Length' was also the length between perpendiculars, except that the length was taken from the after side of the stem to the fore side of the sternpost, the 'Length Between Perpendiculars, Molded'.

Length Overall: This was the length as measured from the foremost tip of the stem bar to the aftermost tip of the overhang of the stern.

Registered Length: This was measured from the fore side of the tip of the stem bar to the after side of the sternpost.

Extreme Breadth: This was measured over the outside plating at the greatest breadth of the vessel. This was also the 'Registered Breadth'.

Breadth Molded (B): This was taken over the frames at the greatest breadth of the vessel.

Depth Molded: This was measured at the middle of the length, from base line to top of beam at side of uppermost continuous deck.

Lloyd's Depth (D): This was measured at the middle of the length, from top of keel to top of beam at side of uppermost continuous deck.

Framing Depth (d): This was measured vertically at the middle of length, from top of keel at center, or double bottom at side, to top of lowest continuous deck or tier of beams at side.

Depth of Hold: This measurement – also called the 'Registered Depth' – was taken in two ways. If a ceiling was laid, this measurement was taken from the top of the ceiling on the double bottom at the middle of the vessel's length; if no ceiling was laid, from the Tank Top plating. From this point, the measurement was taken to the beams of the Upper Deck.

The next step was to calculate the scantling numbers for the various parts of the vessel:

B + D was termed the Transverse, or Framing Number.

L x (B + D) was termed the Longitudinal, or Plating Number.

(B / D) regulated the frame spacing and scantlings of floors, and was considered in association with (d) below which regulated the scantlings of frames, reverse frames, and web frames.

L x (B + D) regulated the scantlings of keel, stem, stern post, side and bottom plating, double bottom, side stringers, keelsons, lower deck stringer plates, and lower deck plating; and, when considered in association with the proportions of the vessel, regulated the thickness of side plating and deck plating of the Upper, Awning, and Shelter decks.

(B) regulated the number of keelsons.

(d) regulated the frame scantlings and the number of side stringers. The length of amidship beams, considered in association with the number of rows of pillars, regulated the scantlings of beams.

In considering the overall hull as a large box girder, material was concentrated at the upper flange by making the Bridge and Shelter Deck plating and sheer strakes of greater thickness and by fitting doublings at these points, while the lower flange was strengthened by doubling the bilge plating. The material used throughout the construction of *Titanic*'s hull was mild steel produced by the Siemens-Martin process.

Once the plans were prepared and the scantlings determined, the next step was to determine the lengths of the individual plates from a prepared model. It was Harland & Wolff's practice to construct a longitudinal half-model of each vessel in wood to a scale of ¼in to 1ft. Previously, it was possible to manipulate these models by

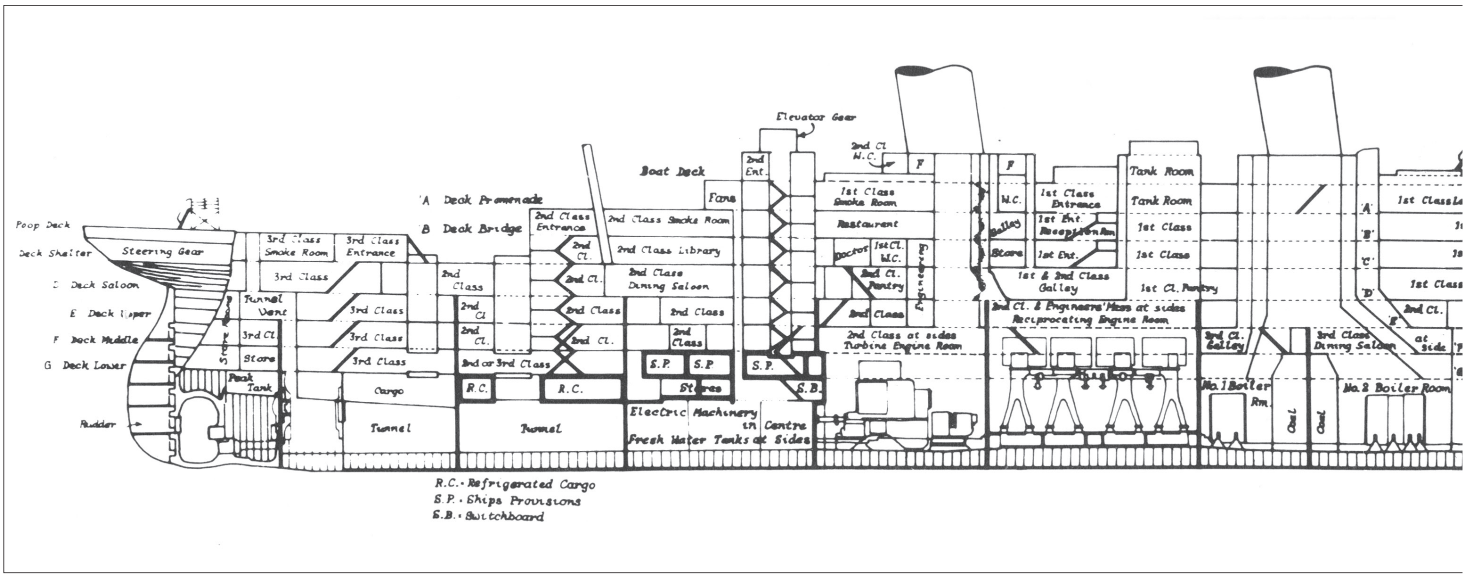

Poop Deck
Deck Shelter
C Deck Saloon
E Deck Upper
F Deck Middle
G Deck Lower
Rudder
Steering Gear
3rd Class Smoke Room
3rd Class Entrance
3rd Class
Tunnel Vent
3rd Cl.
Store
Store Room
Peak Tank
3rd Class
3rd Class
3rd Class
Cargo
Tunnel
A Deck Promenade
B Deck Bridge
2nd Class
2nd Cl
2nd Cl.
2nd or 3rd Class
R.C.
R.C.
Tunnel
2nd Class Entrance
2nd Cl.
2nd Cl.
2nd Class
2nd Cl.
2nd Class Smoke Room
2nd Class Library
2nd Class Dining Saloon
2nd Class
2nd Class
S.P.
S.P
Stores
Electric Machinery in Centre
Fresh Water Tanks at Sides
Boat Deck
Fans
Elevator Gear
2nd Ent.
S.P.
S.B.
2nd Cl W.C.
F
1st Class Smoke Room
Restaurant
Doctor
1st Cl. W.C.
2nd Cl. Pantry
2nd Class
Engineering
2nd Class at sides
Turbine Engine Room
F
W.C.
Galley
Store
1st Class Entrance
1st Ent. Reception Rm
1st Ent.
1st & 2nd Class Galley
2nd Cl. & Engineers' Mess at sides
Reciprocating Engine Room
Tank Room
Tank Room
1st Class
1st Class
1st Cl. Pantry
3rd Cl. Galley
No. 1 Boiler Rm.
Coal
Coal
3rd Class Dining Saloon
'A'
'B'
'C'
'D'
'E'
2nd Cl.
at side
No. 2 Boiler Room
R.C. - Refrigerated Cargo
S.P. - Ships Provisions
S.B. - Switchboard

Fig. 1-12 **Inboard Profile** – This is a typical example of an Inboard Profile plan for *Titanic*. A drawing like this would be traced for many uses such as the water pipe schematics. This specific plan was similar to that used during the Board of Trade investigation into the sinking, and would have been close to that which was given as an initial drawing to the Board of Trade.

hand into the positions required by the plating designers. As the size of the models increased along with the size of the vessels, it became necessary to provide a special frame in which the model was mounted, allowing it to be easily turned and held at the desired angle. Such an apparatus, designed by Alexander Carlisle, was used for the 400/401 half-model. It consisted of an oblong table on which the model was mounted about chest high. By an arrangement of worm-and-worm-wheel, gearwheels and racks, the model could be revolved on its longitudinal axis and stopped in any desired position. Without this apparatus eight men would have been required to shift the half-model for 400/401, which weighed nearly half a ton.

The edges and butts of the shell plating and lines showing the positions of the frames were marked on this half-model, which was also used for the preliminary fairing of the sight edges of the plate strakes. The lengths and shapes of the plates were measured from this model and the materials were then ordered from the steel mill.

It was common to order the shell plates in sizes 1in larger overall than the sizes taken from the model, except at the curved parts of the bow and stern, where an excess of 2 to 4in was specified. The additional material was to allow for trimming to finished size after the various bending and shaping operations had been performed. In most shipyards, the breadths of the plates were taken from the scrive board. The lengths of floors and reverse frames were sometimes obtained from the Body plan or from the scrive board. The developed lengths for the frames and the types of riveting to be employed for 400/401 were indicated on a drawing called a 'Framing Plan'.

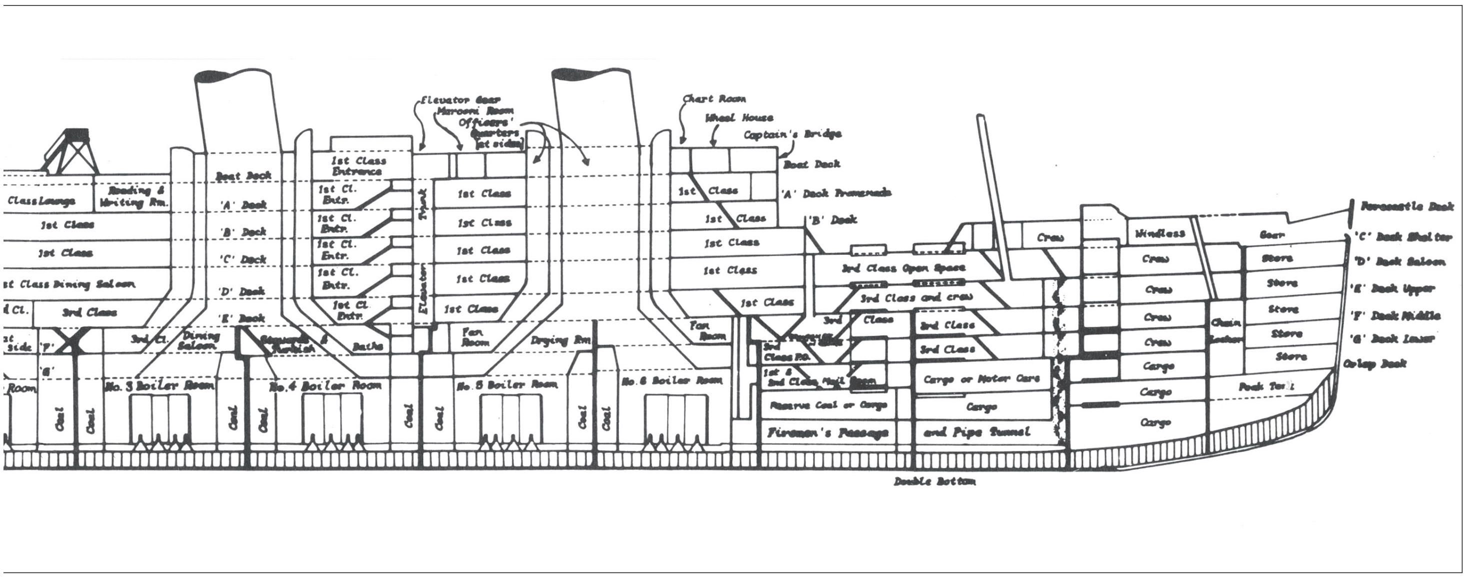
CONSTRUCTION BEGINS

Ordering and constructing of parts

At the start of 1909, Harland & Wolff employed some 12,000 people in fifty-three offices and construction shops, divided into two areas – shipbuilding and engineering – with five main departments.

Construction officially began with the ordering of parts. As construction on 401 was to begin shortly after the start of 400, many of the fittings were ordered at the same time. To accomplish this efficiently, one standard for ordering was adopted by many shipyards. Order forms were prepared in 'order of installation' sequence. This sequence was generally as follows: Flat Plate Keel, Stem, Stern Frame, Bottom Plating (Plating to Turn of Bilge), Floors and Keelsons, Tank Top, Side Framing, Stringers, Side Plating, Bulkheads, Girders and Pillars, Decks, Hawse Pipes, Stern Tubes, Struts, Guards and Fenders, Sea Connections, Foundations, Hatches, Manholes, Doors, Skylights and Scuttles, Ladders, Air Ports, Rudder, Deck Erections, Rail and Awning Stanchions, Masts and Rigging, Ceiling Auxiliaries, Steering Gear, Bilge and Ballast Systems, Piping, Plumbing, Heating System, Electric Lighting, Ventilation, Refrigerating Plant, Painting, Furniture, Storerooms, Deck Covering, Boats and Boat Gear, Outfit Canvas Work, Upholstery, Equipment, Stores, etc.

While the preceding list is a guide to the sequence in which the structure of a vessel may be erected and parts must be ready for fabrication or installation, shops at the Harland & Wolff yard would begin work on upcoming projects as soon as possible without regard to whether the items were needed immediately or not. Work began


Elevator Gear
Marconi Room
Officers' Quarters (at sides)
Chart Room
Wheel House
Captain's Bridge
Boat Deck
'A' Deck Promenade
'B' Deck
Class Lounge
Reading & Writing Rm.
1st Class
1st Class
st Class Dining Saloon
d Cl.
3rd Class
st Side
'F'
'G'
Room
Boat Deck
'A' Deck
'B' Deck
'C' Deck
'D' Deck
'E' Deck
3rd Cl.
Dining Saloon
Stewards & Turkish
1st Class Entrance
1st Cl. Entr.
1st Cl. Entr.
1st Cl. Entr.
1st Cl. Entr.
1st Cl. Entr.
Baths
Trunk
Elevator
1st Class
1st Class
1st Class
1st Class
1st Class
Fan Room
Drying Rm
1st Class
1st Class
1st Class
1st Class
1st Class
Fan Room
3rd Class P.O.
1st & 2nd Class Mail Room
Reserve Coal or Cargo
Fireman's Passage
3rd Class Open Space
3rd Class and crew
3rd Class
3rd Class
3rd Class
Cargo or Motor Cars
Cargo
and Pipe Tunnel
Crew
Windless
Gear
Crew
Crew
Crew
Crew
Cargo
Cargo
Cargo
Chain Locker
Store
Store
Store
Store
Store
Peak Tank
Forecastle Deck
'C' Deck Shelter
'D' Deck Saloon
'E' Deck Upper
'F' Deck Middle
'G' Deck Lower
Orlop Deck
No. 3 Boiler Room
No. 4 Boiler Room
No. 5 Boiler Room
No. 6 Boiler Room
Coal
Double Bottom

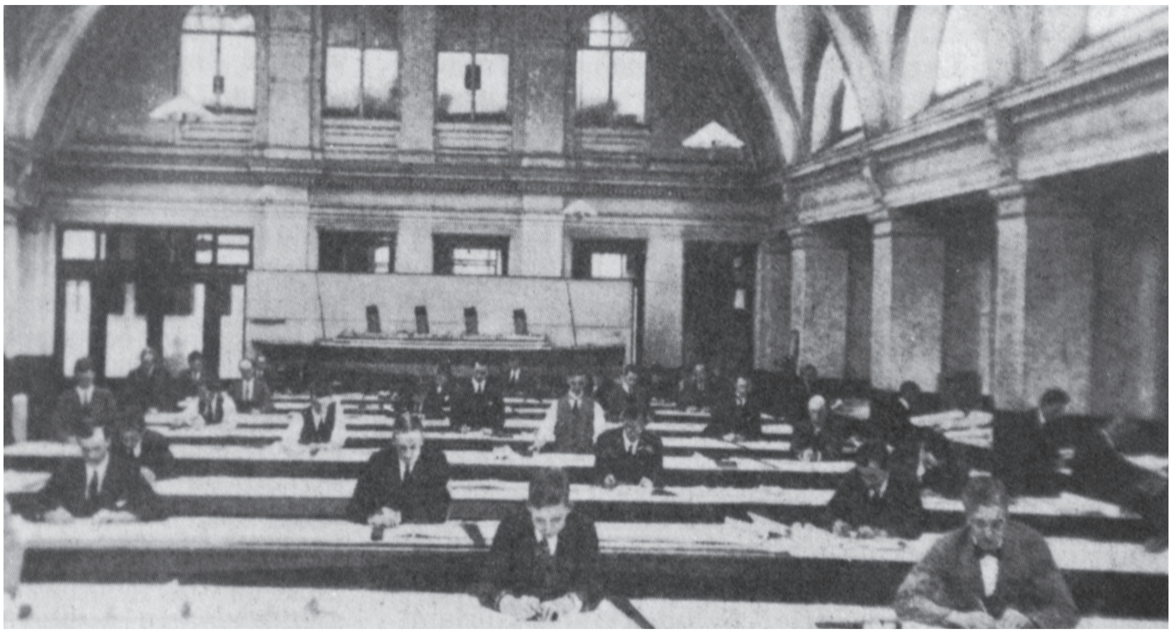


Fig. 1-13 **Drawing Office** – The drawing office at Harland & Wolff. A half-model of *Olympic* mounted to a board is visible at the back of the room. *(*Engineering*/Authors' collection)*

on fittings such as doors, hatches and manholes as soon as the plans became available, thereby providing work for the Blacksmith, Pattern, Foundry, Machine and Galvanizing Shops. The completed fittings would then be stored until required.

As previously stated, preliminary drawings were essential to the ordering of material. In order to make these drawings, a Lines plan was developed from which was determined the form of the vessel for which the material was needed. One duty of the Planning Department was to keep apprised of progress in the Drafting Room so that as soon as the lines plan for a new vessel was completed, prints and a preliminary table of offsets could be issued to the Mold Loft, and the ordering of fittings could be undertaken.

Special attention was given to the ordering of heavy castings such as the stern frame, propeller shaft brackets, struts, stem, etc., to avoid delays. The necessary plans were made and the castings ordered as soon as practical following the completion of the schedules for structural material. In addition to the duties previously described, the loftsmen were also responsible for using the detailed

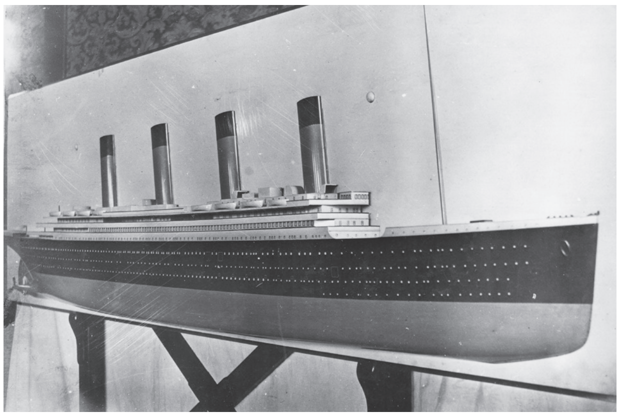


Fig. 1-14 **Half-Model** – A half-model similar to this one, but minus all structures above the main strength deck and painted overall in white to provide a drawing surface, would have been used for final fairing of the strakes of the shell, and then for lifting the shape and size of all of the shell plates. This model, like the one shown in Figure 8, is an early rendition of the *Olympic*, and was used for general reference purposes. The actual half-model used in design and ordering of the plating was most likely destroyed long ago. *(H&W/Authors' collection)*

plans supplied to them from the Drawing Office to draw the stem bar, stern frame, rudder frame, etc., at full size. From these, the Pattern Shops produced full-size wooden templates to be sent to the makers of these parts, whether they were forgings or castings.

A good example of the difficulties involved in the fabrication and delivery of such large components can be found in castings for the stern frame of the *Titanic*, which were far more elaborate than those of the average ship of the time. The making of the molds in which the stern frame was cast represented two months' work. Another five months were required for the completion of the finished castings, for a total of seven months' time. In casting the pieces making up the stern frame alone, about 95 tons of molten steel were required, the finished weight of these pieces being some 70 tons. Not unexpectedly, construction of 401 was delayed due to problems in delivering some of the large steel castings from the Darlington Forge Company.

Material orders were prepared by the Planning Department and were subject to the approval of the managing naval architect. As the representative of the engineering divisions of the yard, the naval architect determined the specification requirements of the material and equipment going into each ship. The actual placing and handling of orders was assigned to the purchasing agent, also subject to the approval of the managing naval architect. Material received in the yard before it was required was stored until it was needed.

Deck plates, stringer plates, and both longitudinal and diagonal tie-plates were measured from the deck plans, with an excess of ½ to 1in over the net lengths and breadths. The dimensions of coaming plates to hatchways and the lengths of stringer and waterway angle bars were measured from the deck plans, but the lengths of all beams were obtained from the scrive board.

Although desirable in order to secure the best possible arrangement in the vessel, the butts of keelson angles, plates, etc., were not always set off upon the working plans. Generally, the practice was to measure the total lengths of the keelsons, bilge, and side stringers, and subdivide them into convenient lengths of from 40 to 80ft and leave it to the foremen at the ship to arrange the butts in a satisfactory manner.

In a break from the traditional practice of numbering a ship's frames beginning at the sternpost and progressing forward, Harland & Wolff numbered the frames of these ships from amidships starting with two frames numbered '1F' and '1A' ('F' meaning forward and 'A' meaning aft) and then counting upwards, both fore and aft. The same numbers were employed for the corresponding reverse frames, tank floors and beams. The strakes of shell plating were distinguished alphabetically, the central keel plate being known as strake 'A', the adjacent garboard strakes 'B', and so on continuing upwards to the sheer strake. The plates in each strake were numbered commencing from forward. The strakes of deck plating were also marked alphabetically, with individual plates distinguished numerically. All plates within a steel deck having the same dimensions and thickness were marked by a common identifier when ordering the materials in order to reduce the number of alphabetical or numerical designations. Therefore, it was necessary to state how many plates of each size were required when placing an order.

These practices were, however, simply matters of detail; the general principle was that the materials upon reaching the shipyard were individually chalked or painted with numbers corresponding to numbers appearing on the main construction drawings. These pieces were then stored away until needed by the shops, or by the shipwrights doing the assembly work, even though the materials might not be needed for weeks or months after their arrival.

Laying the blocks

After materials were ordered, the preparation of the foundation upon which to build the ship commenced. The keel blocks were placed at a declivity somewhat less than the ways subsequently laid for launching. The commonly adopted declivity for blocks when a vessel was launched end-on was about 5/8in per foot.

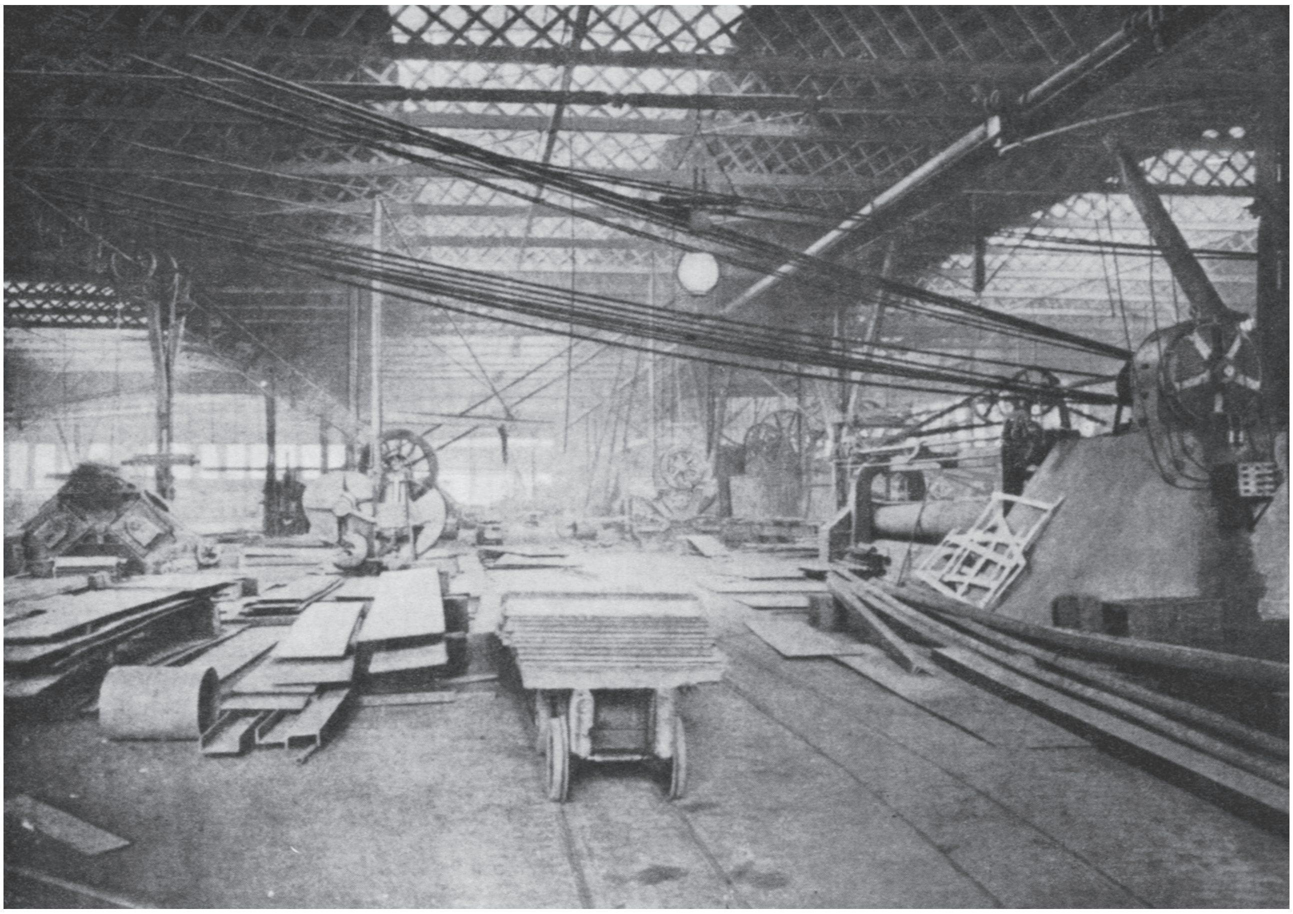


Fig. 1-15 **A Portion of one of the Platers' Sheds.** (The Engineer/*Authors' collection)*

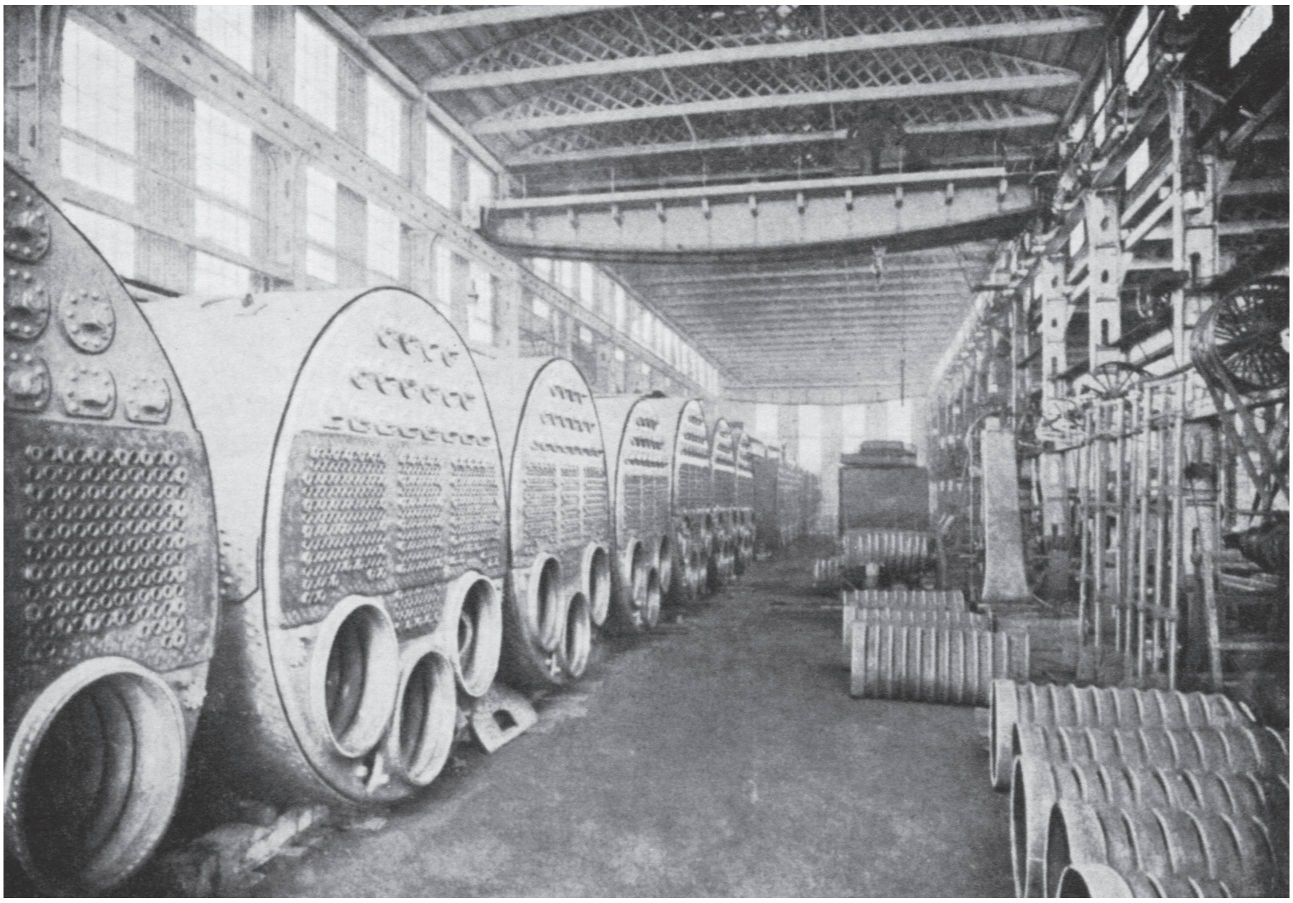


Fig. 1-16 **A Portion of the Boiler Shop.** (The Engineer/*Authors' collection)*

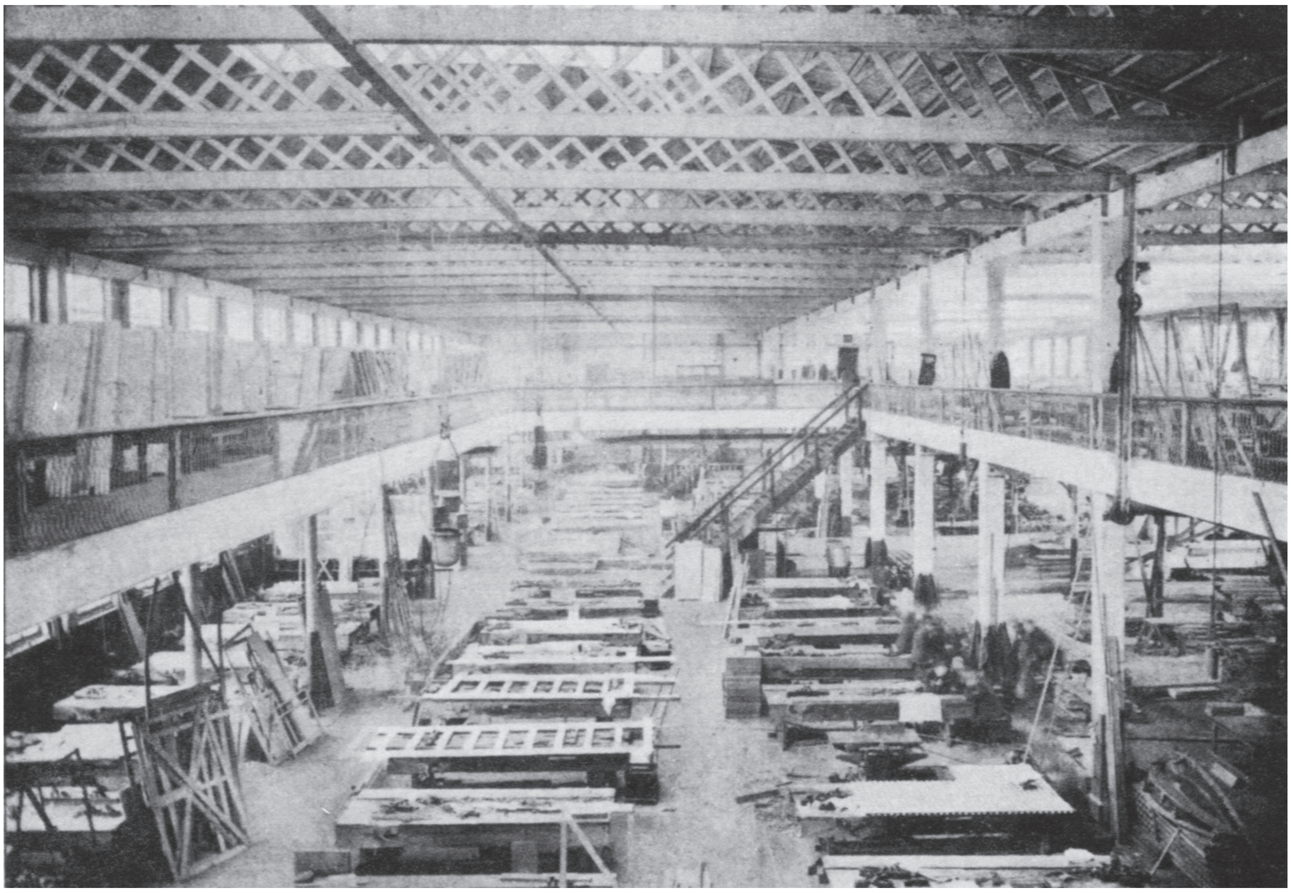


Fig. 1-17 **A Portion of the Joiners' Shop**. (The Engineer/*Authors' collection)*

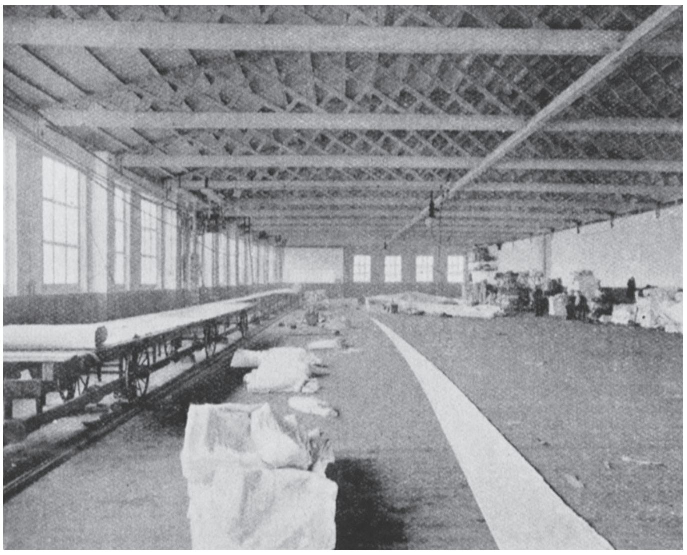


Fig. 1-18 **Awning and Sail-making Shop**. (The Engineer/*Authors' collection)*

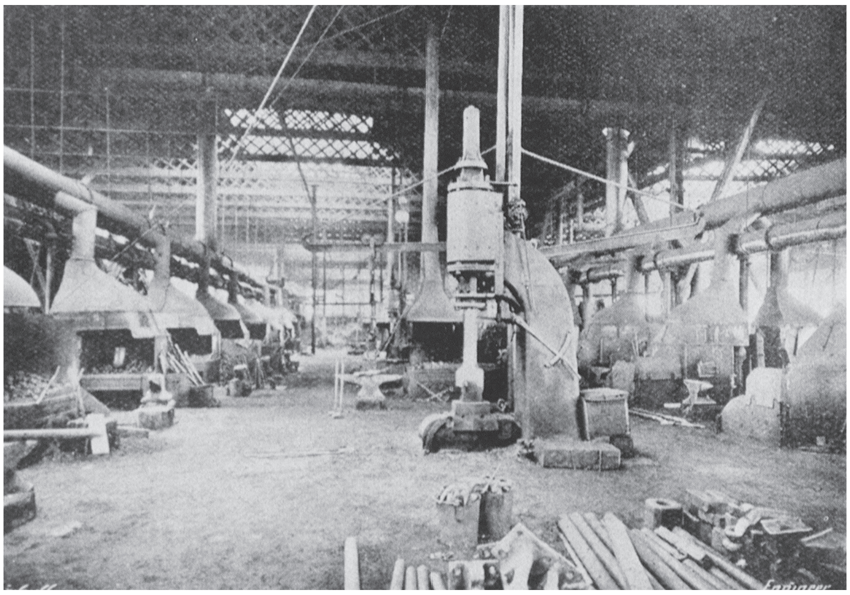


Fig. 1-19 **The Smiths' Shop in the West Platers' Shed.** (The Engineer/*Authors' collection)*

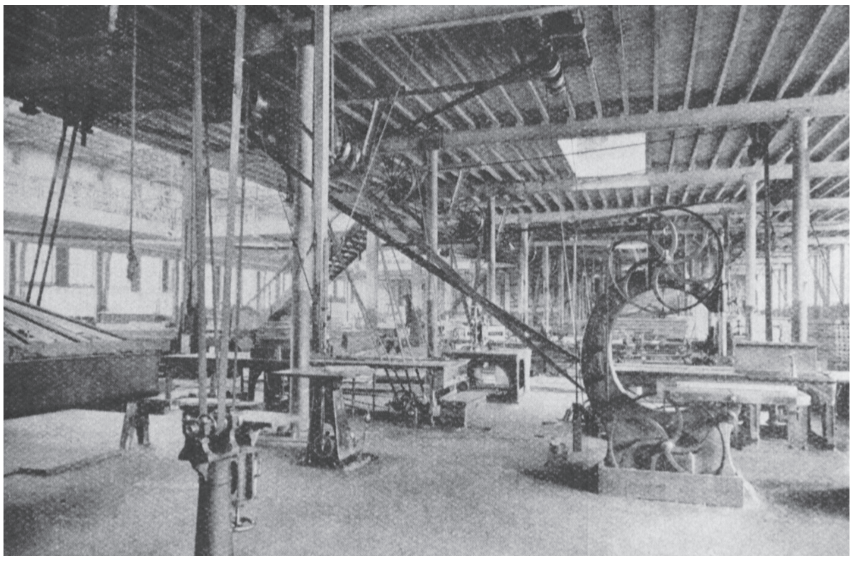


Fig. 1-20 **The Joiners' Shop.** *(*The Engineer/*Authors' collection)*

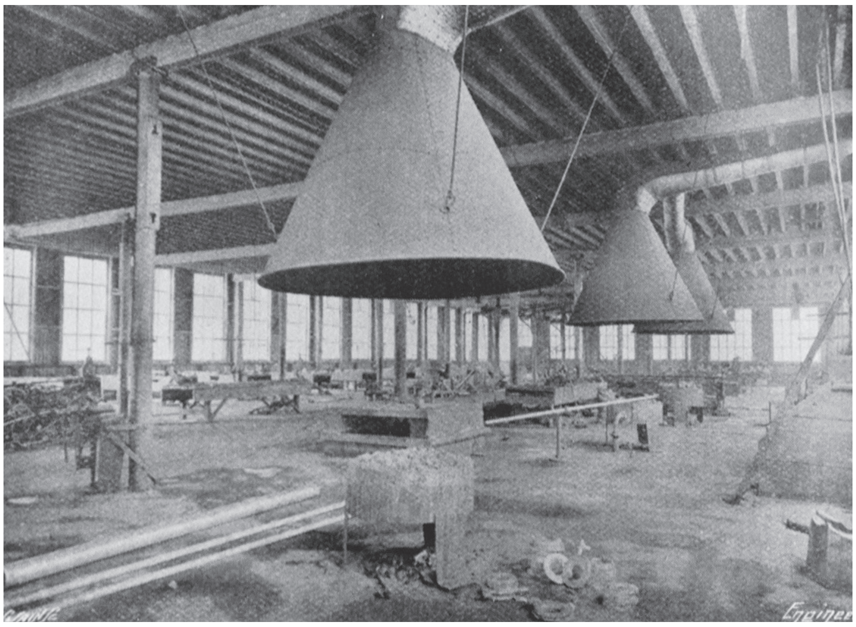


Fig. 1-21 **The Plumbers' Shop**. *(*The Engineer/*Authors' collection)*

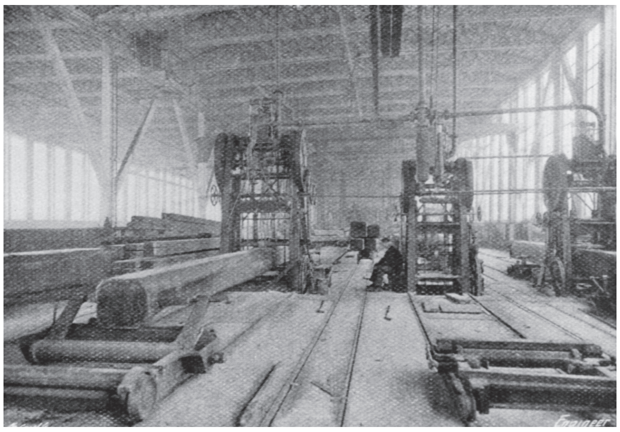


Fig. 1-22 **The Saw Mill.** *(*The Engineer*/Authors' collection)*

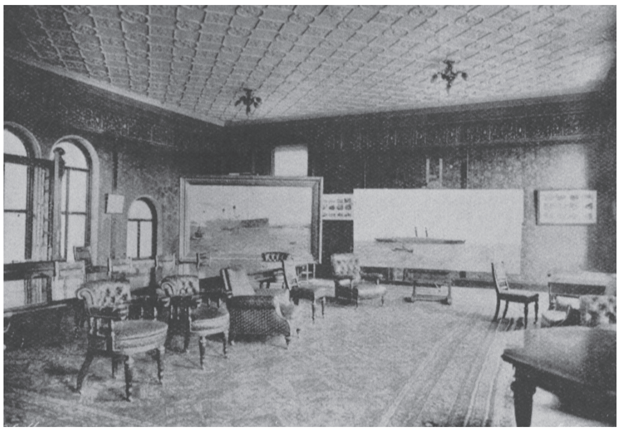


Fig. 1-25 **The Consultation Room**. *(*The Engineer*/Authors' collection)*

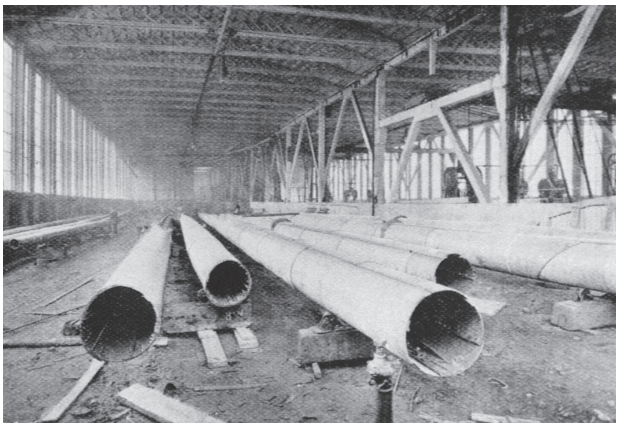


Fig. 1-23 **The Steel Mast Shed**. *(*The Engineer*/Authors' collection)*

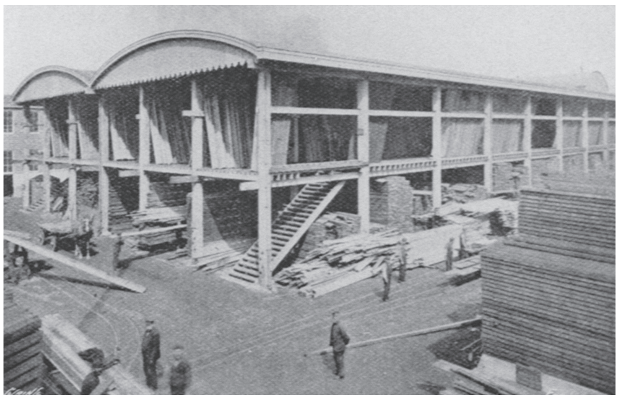


Fig. 1-24 **Timber Drying Sheds**. *(*The Engineer*/Authors' collection)*

The blocks for *Titanic* were made of pitch pine 14 to 15in square and spaced 4ft apart, with care taken to ensure the vessel was sufficiently raised above the ground for the proper performance of all the operations involved in construction. The foremost block was invariably the highest as the excess in declivity of the launching ways over that of the blocks tended to bring the bow of the vessel continually nearer the ground as she slid into the water. The intended height of the ways, the nature of the foreshores, and the declivity adopted in launching were all considered in determining the height of this foremost block. If the blocks were laid at the same declivity as was subsequently adopted for the launching ways, the height of the foremost block would be determined solely by the necessity of affording sufficient headroom for working under the flat of the bottom. But if the declivity of the keel blocks was less than that of the launching ways, care was taken that the fore part of the keel would not be not brought too near the ground when the stem had reached the bottom of the ways and the after part of the vessel was waterborne. It was an advantage when the ground upon which the vessel was built had the same natural declivity as was given to the launching ways. In such a circumstance, it was common to lay the blocks at a uniform height throughout the entire length of the vessel. The slip upon which *Titanic* was constructed was laid at ⅜in per foot declivity. The declivity of the ways was ⅜in per foot forward for half their length, increasing to ½in per foot for the remainder.

Tonnage

It is important to understand the meaning of the term 'tonnage' and to clarify its association with the design of a ship. The amount of space that is within a vessel affects many variables, including taxes, and therefore, the ship's monetary earning potential.

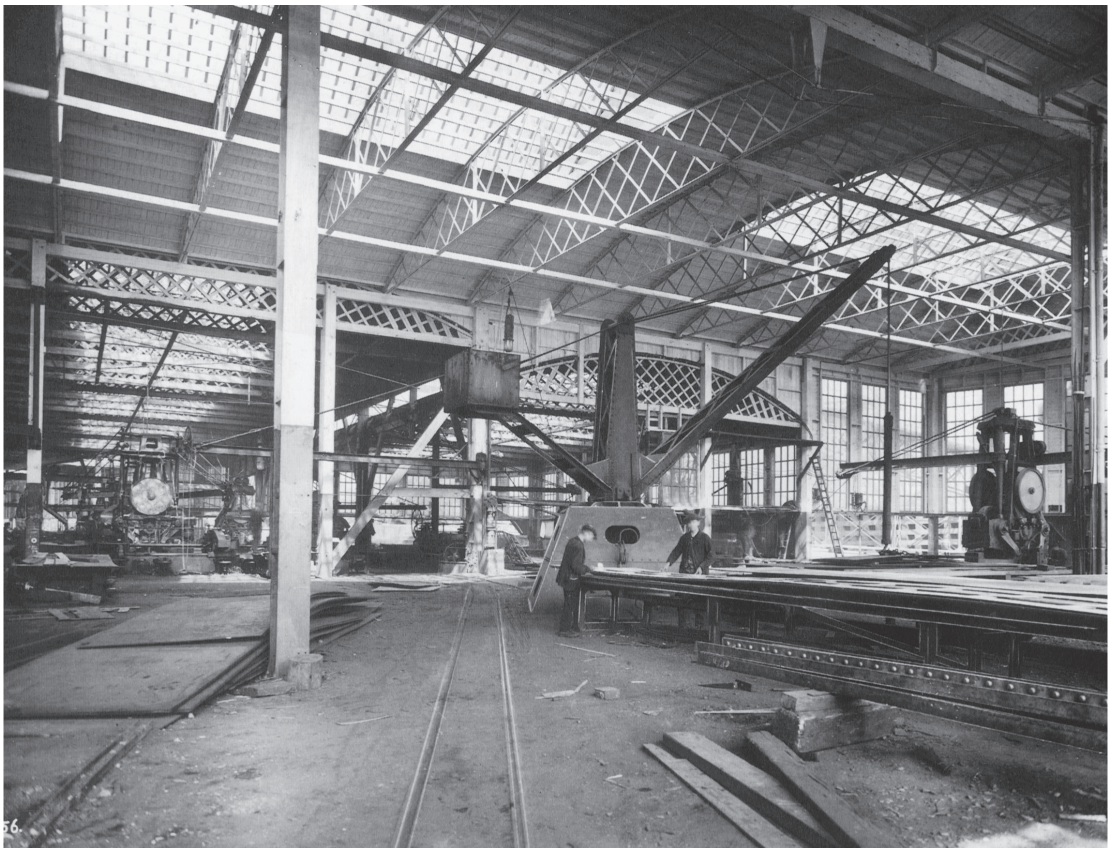


Fig. 1-26 **North Yard Platers' Shed**. (The Engineer/*Authors' collection)*

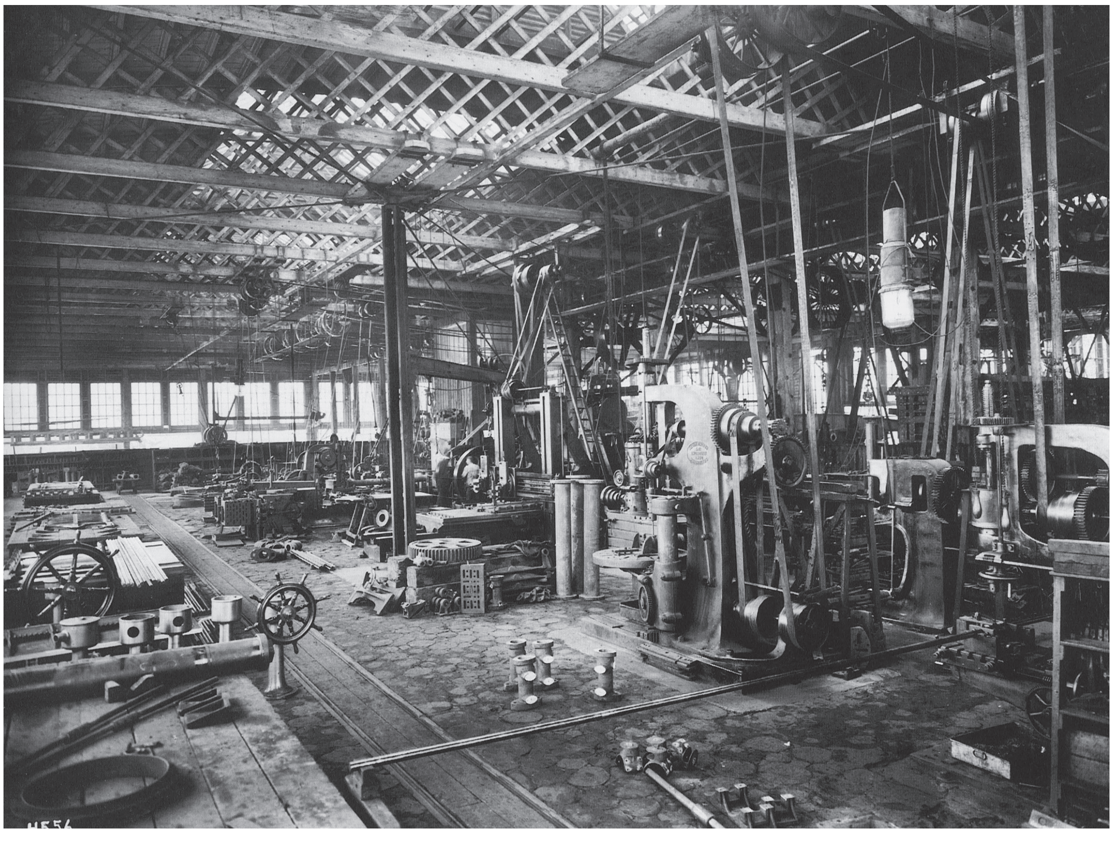


Fig. 1-27 **The Fitters' Shop.** (The Engineer/*Authors' collection)*

In early Egyptian and Phoenician times it became apparent that length, breadth and depth did not adequately express the earning capacity of a vessel. Thus, a new means of determining a vessel's carrying capacity became necessary in order to distribute equitably the various harbor dues, etc., among the vessel owners.

Tonnage measurements originated in the thirteenth century during a period when vessels were carrying large amounts of wine. Wine was usually transported in a large cask or barrel known as a 'tun' which, when full, held 250 gallons, occupied approximately 57 cubic ft of space in the ship and weighed 2,240lb. In the fifteenth century, these space and weight numbers were formally established by law in England as 1 tun. As taxes or port dues were paid in actual tuns of wine, those payments came to be called 'tunnage' – indicating the number of tuns a certain vessel had to pay as fees based upon the number of tuns she could carry. The spelling of the word eventually changed to 'tonnage'.

Confusion still existed as to what should be used to express the earning ability and basis for taxation of a ship, the space available in the vessel for stowage of cargo, and the actual weight that could be carried. The intent was to base tonnage on the earning space in the vessel rather than on the weight the vessel could carry. 'Simpson's rule'[4] became the standard used to determine the volume of earning space in cubic ft. This volume was then divided by 100, giving the tonnage of the vessel. Therefore, this tonnage reflected 'space' tonnage, not 'weight' tonnage. 'Gross Tonnage' referred to the total volume of enclosed space within a vessel. However, as noted, not all space within a vessel was available for cargo. 'Gross Register Tonnage' is Gross Tonnage less allowances for certain spaces such as deckhouses, air shafts, and bridge spaces; 'Net Register Tonnage' does not include engine and machinery spaces and like areas, and represents the volume of the ship available for carrying cargo and passengers.

The actual rules for working out the tonnage were complicated. The unit of measurement of 100 cubic ft of space per ton for gross and net tonnage was adopted as a standard by Great Britain in 1854. The rules for calculating tonnage used for the *Titanic* were contained in a booklet entitled 'Instructions Relating to the Measurement of Ships' issued by the Board of Trade. The specifications outlined in this publication were established in 1873 when a meeting of the International Tonnage Commission was held in Constantinople. Attempts to standardize ship tonnages internationally were never successful; however, the systems of measurement required by various governments were essentially similar and were best exemplified by the original Middle Eastern system noted above.

Surveyors for the Board of Trade made tonnage measurements while the vessel was under construction. After completion, *Titanic* received an official document issued by the Board of Trade known as the 'Certificate of Registry' which not only certified the tonnage, but certified that the law had been complied with in all respects. Every sea-going ship over 15 tons burthen sailing under the British flag also had to be registered.[5] To be registered, each ship had to declare a 'port of registry'. The choice of port of registry was up to the owner and was not necessarily the port to which the ship traded or the owner's place of residence. For *Titanic*, her stern would read 'Liverpool' to reflect her port of registry.

Titanic's Certificate of Registry was issued on March 25, 1912, giving *Titanic* a Gross Tonnage of 46,328.57 tons. This was just over 1,000 tons greater than *Olympic*, making *Titanic* – to the delight of White Star advertising copywriters – the largest ship in the world.

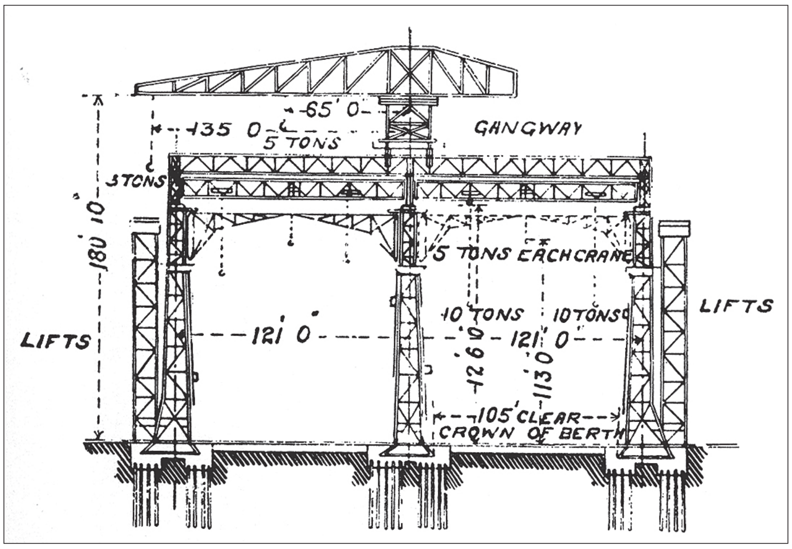


Fig. 1-28 **Section of Gantry over Slips Nos 2 and 3.** (The Engineer/*Authors' collection*)

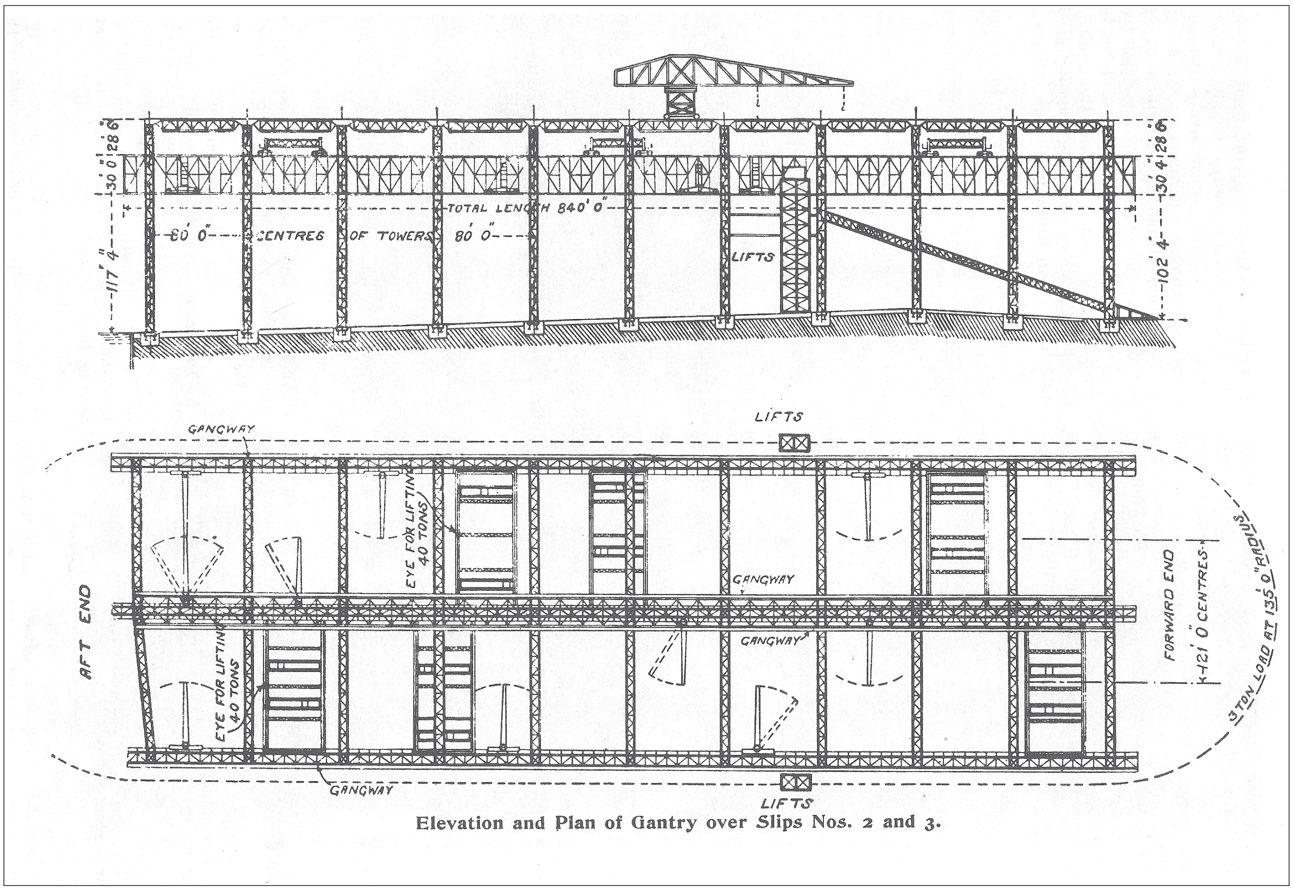

30' 0"
28' 6"
TOTAL LENGTH 840' 0"
80' 0"
CENTRES
OF TOWERS
80' 0"
LIFTS
117' 4"
30' 4"
28' 6"
102' 4"
GANGWAY
LIFTS
AFT END
EYE FOR LIFTING 40 TONS
EYE FOR LIFTING 40 TONS
GANGWAY
GANGWAY
GANGWAY
FORWARD END
121' 0" CENTRES
3 TON LOAD AT 135' 0" RADIUS
LIFTS
Elevation and Plan of Gantry over Slips Nos. 2 and 3.

Fig. 1-29 **Elevation and Plan of Gantry over Slips Nos 2 and 3.** (The Engineer/*Authors' collection)*

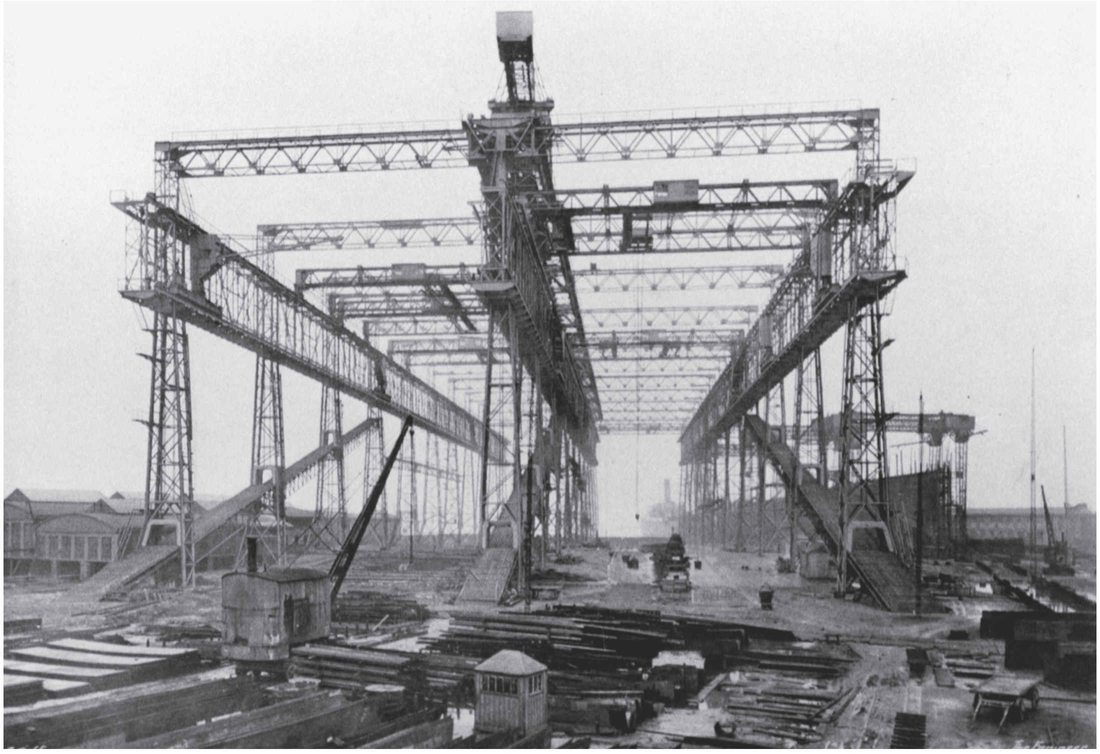


Fig. 1-30 **Gantry and Crane Equipment** – Shipbuilding berths with keel plate of *Olympic* viewed from the forward end, January 1, 1909. (The Engineer/*Authors' collection)*

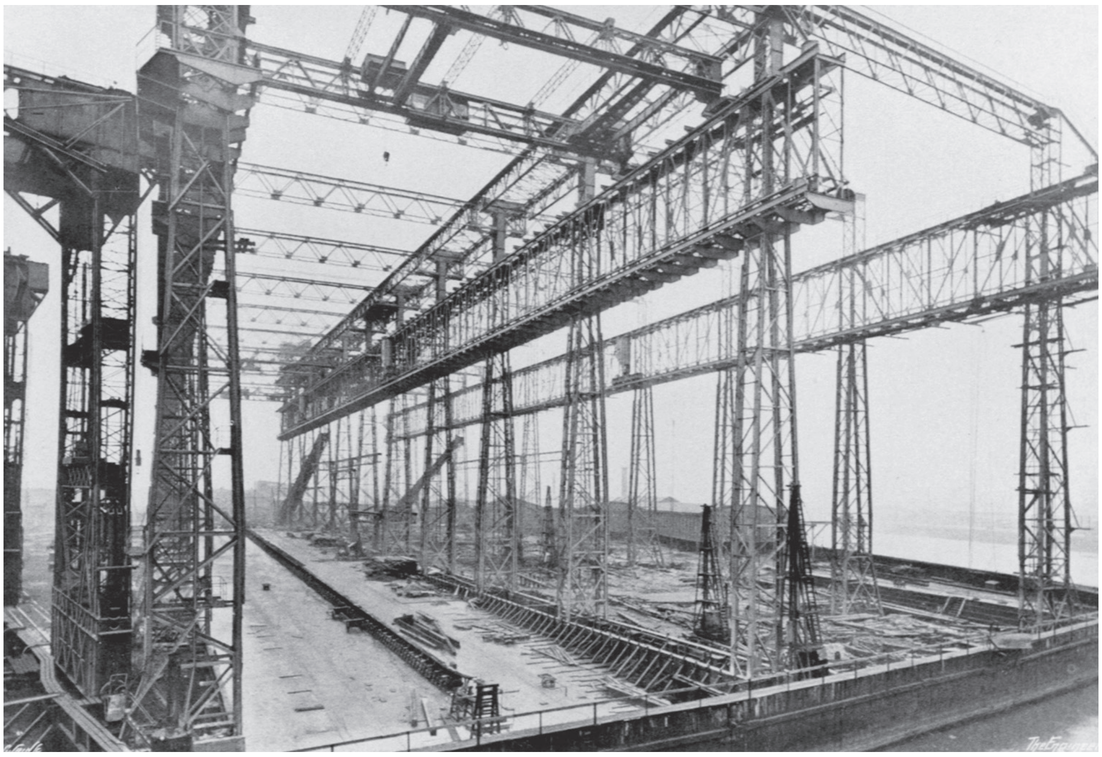


Fig. 1-31 **Gantry and Crane Equipment –** Shipbuilding berths with keel of *Olympic* viewed from the after end, January 1, 1909. (The Engineer/*Authors' collection)*

Notes

1. There is an apocryphal story of an after-dinner conversation between J. Bruce Ismay and Lord Pirrie which supposedly resulted in the conception of the *Olympic*-class liners. As often as this tale has been repeated, the authors have yet to find a primary source confirming the story's validity.
2. *The Engineer*, Harland and Wolff's Works at Belfast, supplement, June 18, 1909.
3. This designation, which applied to a fore-and-aft rigged vessel of two or more masts, must be taken in the context of the time, when sailing merchant vessels were still common and when many older steamships carrying masts for auxiliary sail were still in service.
4. In 1737 Thomas Simpson, an English mathematician and writer, devised what is known as Simpson's Rule, which simplifies the calculation of areas under graphic curves. He also worked out a formula that can be used to find the volume of any solid bounded by a ruled surface and two parallel planes.
5. The register book was kept by the Chief Officers of Customs at ports approved for the registration of ships.

Chapter 2

Structural Members

Ship construction was, and is, the result of centuries of experience. At the time of *Titanic*'s inception, ship construction had reached a point where standard proportions had been established for nearly all vital features. However, the first part of the twentieth century was a time of rapid advances in which new patents and inventions from all scientific and engineering disciplines were incorporated into the art of shipbuilding, with many of these advances being put to practical use by naval architects before they had been fully accepted by their land-based peers. The pace at which technology was advancing was so fast that 'state-of-the-art' fittings on a newly completed ship could become outdated within a few years. *Titanic* was representative of this time of constant evolution, combining the best of traditional practices with the latest improvements of her day.

The structural design and arrangement of any ship includes a multitude of parts chosen for strength, watertightness and/or safety. Generally speaking, the ship as a whole can be regarded as a huge box girder, three sides of which are composed of the shell plating and the fourth by the main strength deck – in *Titanic*'s case, the Bridge Deck (B). These four sides of the box girder are, in turn, strengthened by support structures such as the keel, frames, beams, keelsons, stringers, girders and pillars, each of which has its own function within the whole. The keel is the backbone upon which the ship is built and consists of a rigid fabrication of plates and structural shapes running fore and aft along the centerline of the ship. At the forward end, the keel is connected to the stem; at the after end, the keel is connected to the stern frame which supports both the rudder and propellers.

The frames, acting as the ribs of the ship, determine the ship's form. Their lower ends are attached to 'floor plates' – essentially transverse, vertical, deep web frames – which are attached to the keel at intervals, while their upper ends are attached through brackets to beams which supported the decks. Internal bracing is provided by keelsons and stringers running fore and aft. The frames also support and stiffen the shell plating.

The shell plating, in addition to being necessary for watertightness, is one of the principal strength members of the ship. The shell plating runs continuously from the stem to the stern frame and from the keel to the main strength deck and, as noted, forms three sides of the box girder. The plating, aided by the frames, has to withstand the pressure of the water outside and the stresses which arise from outside forces such as the buffeting of the waves or from rubbing against a dock.

The main strength deck, forming the fourth side of the girder, has to be of strong construction. The deck plating is connected to beams which extend from side to side across the ship. Additional strength is provided by doubling plates in regions weakened by openings such as hatchways and companionways as well as beneath all deck machinery, chocks and bitts. The decks are supported from below by girders and pillars as required.

The bottom, sides and main deck of a ship, however, are not strong enough by themselves to withstand the stresses of an ocean voyage without the additional internal stiffening provided by the lower decks and the main transverse bulkheads. In addition to furnishing support for the shell and the decks, the main transverse bulkheads are made watertight, thus subdividing the vessel into watertight compartments so that, in the event of damage, any flooding can be contained. All doors through these bulkheads which are designed to be watertight are fitted with gaskets and are kept clear at all times so that they can be closed at a moment's notice.

MATERIALS USED IN SHIP CONSTRUCTION

The materials listed below were in general use at the time of *Titanic*'s construction:

Wrought iron

The first metal to be used in ship construction was wrought iron. Use of wrought iron for the primary structural

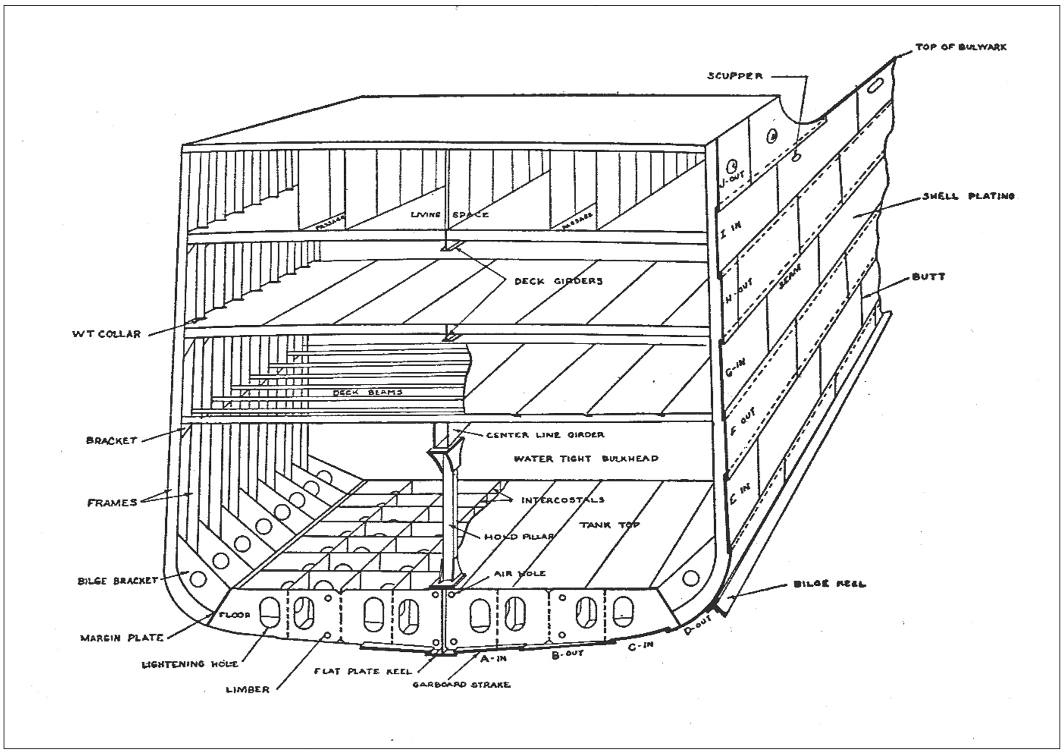

TOP OF BULWARK
SCUPPER
SHELL PLATING
BUTT
LIVING SPACE
PASSAGE
PASSAGE
DECK GIRDERS
WT COLLAR
DECK BEAMS
BRACKET
CENTER LINE GIRDER
WATER TIGHT BULKHEAD
FRAMES
INTERCOSTALS
TANK TOP
HOLD PILLAR
BILGE BRACKET
AIR HOLE
BILGE KEEL
FLOOR
MARGIN PLATE
LIGHTENING HOLE
LIMBER
FLAT PLATE KEEL
GARBOARD STRAKE
A-IN
B-OUT
C-IN
D-OUT
E IN
F OUT
G-IN
H-OUT
SEAM
I IN
J-OUT

Fig. 2-1 **Ship Structure** – This generic illustration identifies the principal parts that comprise a ship's structure.

components was discontinued with the development of the Bessemer and open-hearth (Siemens-Martin) steel-making processes which were less expensive and created a stronger, higher-grade material.

Steel

Mild steel, the type used to the greatest extent in ships of the time, had a carbon content of not more than 0.02 per cent, making it neither too brittle nor too ductile. It was uniform in strength and could be easily worked into any shape. The main disadvantage of mild steel was its lack of resistance to corrosion; this was overcome to a certain extent by careful painting and maintenance.

Forgings

Forgings are made by heating steel to a white heat and then beating it into the required shape by means of a hammer or press. Forgings are used where great strength and toughness were required. The steel ingot used in making the forging was initially formed to shape under a hydraulic press. The ingot was then heated to a white heat in the furnace and moved into a press where operators would control the ingot by the use of a long rod known as a 'porter bar'. The porter bar balanced the weight of the ingot, which was rotated by means of a chain attached at the center of gravity of the porter bar and ingot. Forgings were used principally for rudderstocks, crankshafts, and propeller shafts because, at the time, they were less expensive and tougher than castings. Certain smaller fittings were also forged by the drop-forging process, i.e., by a single stroke of a steam hammer and the use of forming dies. The use of forgings decreased as rapid advances were made in metallurgy and in the techniques of pouring satisfactory steel castings.

Castings

In the manufacture of a casting, a wooden pattern was first made to the exact shape, but slightly larger than the dimensions of the required finished product, to allow both for shrinkage as the casting cooled and to provide additional material to allow machining to finished size. The pattern was placed in special damp casting sand which formed a shell around it. After the pattern was

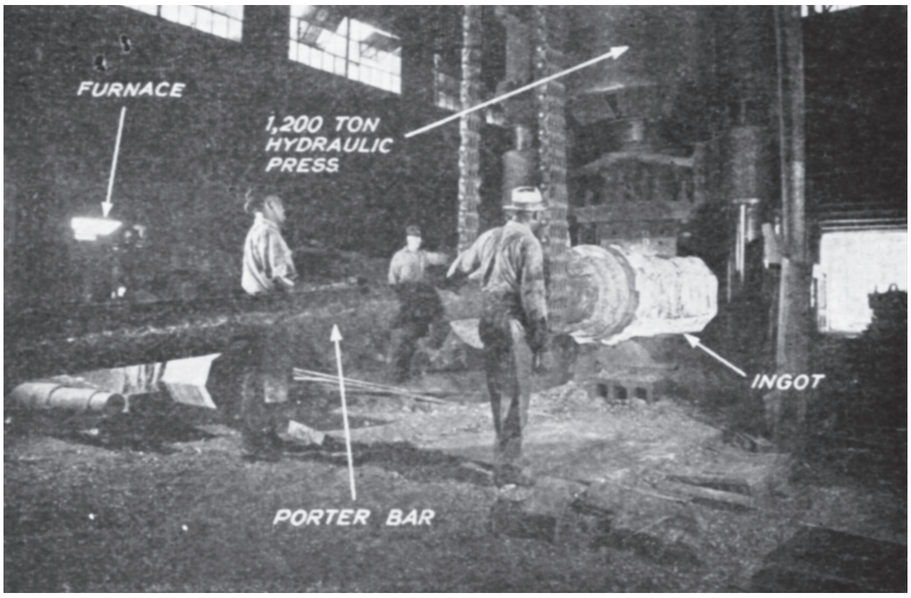


Fig. 2-2 **Forging a Propeller Shaft** – A 30,000lb ingot under a 1,200-ton hydraulic press. The ingot is heated to a white heat in the furnace at left. The operator of the press can be seen at right. The long rod at left, known as a 'porter bar,' balances the weight of the ingot. The ingot is rotated by means of the chain which is attached at the center of gravity of the porter bar and ingot.

removed, molten steel was poured into the void created by the pattern. Components produced from steel castings included the stem, stern frame, stern tubes, rudder, propeller shaft brackets, machinery bedplates, anchors, hawse pipes, chain pipes, pipe flanges and various small hull fittings. The grade of steel used depended on the class of casting.

Plates

Plates are sheets of steel rolled to a uniform thickness of ¼in or more. The inner bottom, bulkheads, deck, shell, trunks, coamings, floors, brackets, girders, built-up sections and many other structural members were made of plate. Plates less than ¼in thick were generally referred to as 'sheets' and their thickness were given in gauges. Sheet stock was only employed for light structures which bore little or no load. Such structures included the walls and roofs of certain deckhouses, and windscreens around entranceways from weather decks. Internally, sheet steel was used to form the partitions of the passenger and crew bathrooms, water closets and galleys, and to enclose shafts between decks such as stairways, ventilation trunks and elevator shafts.

The two principal styles of plate used were 'plain plates' for general work throughout the structure and 'chequered nonskid plates' for work in some areas about the decks and in the machinery spaces. During fabrication, a plate could be drilled, punched, flanged, sheared, planed, beveled, rolled, furnaced, scarfed, countersunk and/or knuckled. Plates fell into three classes in regard to curvature. 'Flat plates' were those with little or no curvature and formed the largest portion of the ship's plating. 'Rolled plates' were those with a cylindrical curvature in one direction only which could be shaped while cold and were usually found at the turn of the bilge in the middle body. 'Furnaced plates' were plates having curvature in two directions. These were heated and hammered out to the required shape.

Shapes

Rolled bars of constant cross-section are called 'shapes'. They are usually made of mild steel but can be made of any other metal that can be passed through the rolls. The typical shapes employed in riveted ship construction were:

Plain Angle

Plain angles were used for frames, beams, hold stringers, and for joining together two pieces of metal that meet approximately at right angles. When the two legs or flanges make a 90° angle, the angle bar is said to be 'beveled'. An angle more than 90° is called an 'open bevel;' an angle less than 90° is a 'closed bevel'. Closed beveling work is difficult, and even when done with care, the heel of the bar is seldom in precisely the same plane as the flange. When mated to the shell, the resulting contact is imperfect unless the projecting part is removed. In riveted work, a further problem arises in that as one flange closes over the other, it becomes difficult to punch rivet holes and to hammer up the rivets. Eventually, in shipbuilding, all angles were arranged to have an obtuse or 'open' bevel with 120° the maximum bevel allowed. If a greater angle was required, a bent plate was used for the attachment.

Bulb Angle

A 'bulb angle' is simply a development of the plain angle in which a small bulb of material has been added to the toe of the angle at the point of highest stress. This made the bulb angle considerably stronger than the plain angle when riveted attachments were used. Bulb angles, used only in riveted construction, were commonly used for frame bars, stringers, bulkhead stiffeners, deck beams and keelsons.

T-Bar

A 'T-bar' can be thought of as an angle having one leg centered on the other. In riveted construction this resulted in a more symmetrical section and a better connection, as it allowed an extra row of rivets to be driven. Since a symmetrical section does not fall over or trip as easily as an asymmetrical one, it was a better section than an angle. However, as with the angle, when riveted to plating as a stiffener, it suffered from a lack of material in the outer fibers.

T-Bulb Bar

The 'T-bulb bar' was developed to correct the deficiency in the T-bar noted above. Material was simply added in the form of a bulb at the bottom of the stem. T-bulb bars were used primarily for bulkhead stiffeners and deck beams.

Channel

A 'channel' is a rolled shape having two parallel flanges on the same side of, and at right angles to, the web. Channels were very useful for side frames, deck beams, bulkhead stiffeners and pillars. However, since they are not truly symmetrical sections, they have a tendency to fold over, or 'trip', under load. They were used extensively in riveted ship work because the upper flange gave a good rivet connection and the lower, highly loaded flange had a plentiful concentration of material.

I- and H-Beams

A rolled shape having a cross-section like the letter 'I' is known as an 'I-beam' and may be considered as a channel with its web centered. This is a truly symmetrical section and for this reason was excellent for deck beams and girders. When the flanges of an I-beam are as wide as the web, it is then called an 'H-beam'. These were used extensively as columns or pillars in the way of engine and boiler spaces. I- and H-beams were not used as pillars in cargo holds as the sharp edges could damage cargo. In these areas, round pillars were preferred.

Rivets and Riveting

It was noted in *The Shipbuilder* that there were 500,000 rivets in *Titanic*'s double bottom alone, the aggregate weight of the rivets being about 270 tons, with the largest rivets being 1¼in in diameter. There were about three million rivets throughout the entire ship,[1] weighing approximately 1,200 tons. An interesting point is that riveters were paid by the rivet, not by the hour, and Harland & Wolff's payroll included 'rivet counters'. *Titanic* was built with two types of rivets, wrought iron and steel. The wrought-iron rivets were closed by hand; the steel rivets were closed by hydraulic riveting machines.

Rivets were made in a 'rivet-heading' or 'bolt-heading' machine (the process of forming rivets and bolts is identical in many ways up to the process of threading). The bar stock from which a rivet is formed is fed continuously in increments into the forming machine, where it comes up against a 'stop' and is then gripped by the gripping die which simultaneously holds the bar stock while forming the neck and shank of the rivet. At nearly the same instant, the stop, which has been set to leave the correct amount of material protruding from the gripping die, moves out of the way to allow the heading punch to advance and forge the shape of the head. The billet remaining in the gripping die is then sheared to the correct length and expelled into a bin beneath the machine. This all happens at fairly high speed and in practically one continuous motion.

Quality of riveted work

The accuracy of the ship designer's calculations and the quality of the material used were ultimately impacted by the precision of assembling the hull. If the innumerable plates and bars comprising the hull were not properly connected to one another, the structure would eventually fail at one or more over-stressed connections. Thus, good workmanship was of the very highest importance in shipbuilding as everything depended upon the quality of the riveting. Bad riveting resulted in enormous expense to the ship owner owing to the delay and cost of effecting repairs; it was not uncommon for a huge liner to be placed in drydock in order to have portions of her shell plating partially or entirely re-riveted. One of the primary sources of trouble in obtaining sound riveted connections was carelessness in the marking off or spacing of rivet holes or in the operation of punching. This produced what were known as 'blind holes' – holes

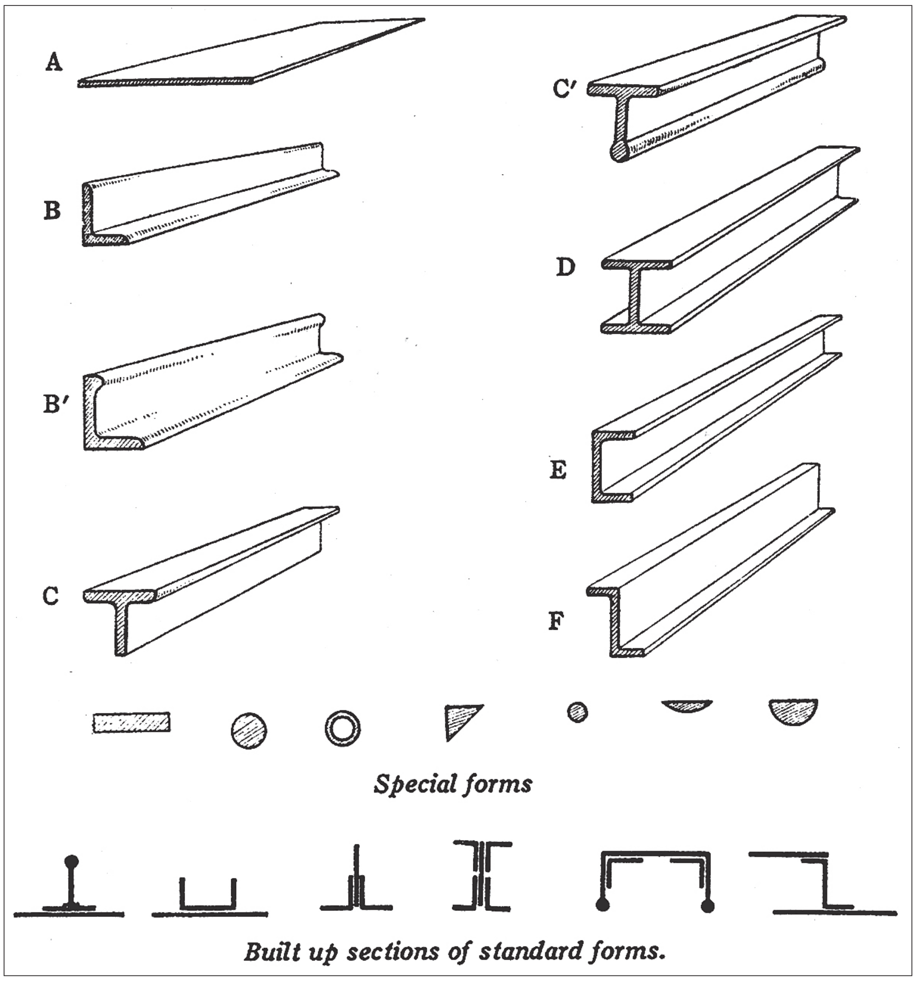


Fig. 2-3 **Rolled Steel Shapes.**
The standard shapes of steel members:

A, the plate, of many sizes and weights
B, the angle, plain and bulb (B'), with legs of various length, and of many weights
C, the T-bar
C', the T-bar with bulb (T-bulb bar)
D, the I-beam
E, the channel
F, the Z-bar

In addition to the standard forms of construction members shown here, certain special forms of material were often employed, such as *half rounds, rods, angle bars, columns, hatch ledges* and some others. The rolled shapes, together with the special forgings and castings formed the component parts of a steel hull.

in overlapping plates or bars which were only partially aligned to one another. In the interest of saving time, many shipbuilders permitted the forcing of rivets through holes that were not in alignment by means of a 'drift punch', a long, tapered steel pin which was used to forcibly pull misaligned holes into alignment while stretching and distorting the metal immediately around the rivet holes. While it was found that good steel was not damaged by light drifting of slightly misaligned holes, where the practice was allowed there was always the temptation to employ the practice to correct more severe misalignments. This often resulted in stress cracking of the steel around the drifted hole, as well as difficulty in obtaining good contact between the faying surfaces of the plates due to amount of upset material remaining around the hole edges. At Harland & Wolff the practice of drifting to correct blind holes was expressly forbidden, as the proper manner in which to correct an obstruction caused by misalignment was by means of a special drill called a 'rimer'.

The tightness of rivets was tested by tapping the side of the rivet head with a small hammer while two fingers of the other hand rested against the opposite side of the rivet head. An experienced workman could immediately detect a loose rivet, which was then drilled out and replaced. The only exception was in the case of a tight rivet in a watertight compartment showing signs of leakage. A plug-head rivet could be satisfactorily caulked watertight. As it was more difficult to obtain tight work where the riveting was more than two-ply, that practice was avoided as much as possible.

Types of rivets

Rivets are designated by the form of their head and point. The head of the rivet is the protrusion formed on the shaft, or 'shank', of the rivet during manufacture by the rivet-heading machine; the point of the rivet is, in essence, a second head which is formed in place during the closing of the rivet.

The massive 'pan-head' rivet was the most common as it was incredibly strong and its large bearing shoulder had a good clamping effect on the plates. The watertightness of a pan-head rivet was assured by the bearing shoulder of its head and its plug-like, tapered neck. It was easily held upright during riveting and its soundness was easily tested. Repeated blows of the holding-up hammer tended to expand and flatten the head, especially if it was soft and hot, and in order that it did not become too flat and button-like, the head was made deep to begin with. Pan-heads differed considerably in their relative proportions.

'Snap-head' rivets were only used in machine riveting. With an attractive, semi-spherical head, this rivet was often employed in areas in which the rivet heads were exposed and where a finished appearance was desirable. The rivet neck was swelled, thus better filling the hole, and the point of the rivet was either beaten down or finished off flush, the rivet hole being well countersunk to accommodate this.

The 'countersunk-head' rivet was employed where a flush, finished surface was required, as in the keel, or in gunwale and other bars against which deck planks or woodwork was fitted. It was also used where watertightness was essential but not easily secured. It was chipped[2] and finished off with small hammers in the same way as a countersunk point. Where a flush surface was not an absolute necessity, it was allowed to remain above flush. The taper of the head was, if anything, formed sharper than the angle of countersink of the hole, to ensure the bottom part filling the countersink; the outer portion of the head was easily expanded by hammer blows. The conical form of the countersunk head made it very efficient regarding watertightness, and because the length of the rivet shank was reduced, it was especially suitable for watertight three-ply riveting found in tank work.

The holes in which countersunk head rivets were installed were usually not countersunk by a secondary operation; instead, the natural countersink created by the hole-punching process was increased by the use of an extra-large die. When finished, this rivet head resembled a large, flat button. In some yards 'bull-head' rivets were preferred to countersunk ones for this work as the head was deeper when finished. The advantage of this class of rivet head lay in the fact that, as the bearing shoulder was formed by the hammering, watertightness was assured despite irregularities in the holding up. It was an ideal rivet to use in places where it could be difficult to hold up but where watertightness was essential. Because of this, these rivets were sometimes employed in the confined spaces of a double bottom, for the Tank Top and for watertight floors.

A 'plug-head' rivet was a pan-head with the shoulder removed. Originally it was thought this design assured that the head, being tapered, could be driven into the hole with an improved degree of solidity and tightness. However, the neck of a well-proportioned pan-head rivet fit no less solidly. In addition, the large bearing shoulder of a pan-head rivet increased the clamping power of the rivet and, under severe stress, tended to strain and distort the joint, check the side-tripping and cause a loosening effect on the rivet. 'Plug-head' rivets were rarely used once it became obvious that they had insufficient clamping power.

'Tap' rivets, also called 'stud' or 'screwed' rivets, were also used in *Titanic*'s construction. The ultimate strength of this type of rivet was little, if at all, inferior to that of clinched or 'through' rivets. However, they were less efficient since they did not fill the holes with absolute solidity, their clamping effect was inferior, and they were liable to become loose through corrosion and wasting of the threads. They were particularly unsuited for connecting thin material as their coarse threads had such a small grip in this type of application. If stress or corrosion occurred, or if the rivets worked back loosening the joint, these rivets would pass right through thin plates; to prevent this, a lock nut could be run up on the projecting point. The use of tap rivets was confined to the riveting of the shell plating to the stern frame, where the above concerns were less important. In these locations, they were as advantageous as they were short and inextensible and did not need to be as large as through-rivets. Through-rivets tended to seriously weaken the forgings and, unless they were closed with the greatest care, the soundness of the finished work would be doubtful. In certain places, such as the upper and lower turns of the bossed portion of the stern frame where an ordinary rivet would not pass squarely through the surface, the use of tap rivets was necessary.

Tap rivets were required to grip tightly in a threaded hole to minimize the chance of loosening under side stress and/or vibration. To ensure this and provide against corrosion of the thread, those in the stern frame entered to a depth at least 1½ times their diameter; this was more than adequate to resist an outward pull. The countersunk head had to be concentric with the shank in order to fit squarely in the countersink of the plate; this was necessary to avoid a one-sided contact that would result in a one-sided straining effect, tending to break off the head. To ensure a proper fit, the rivets were turned rather than formed, and the holes that received them were drilled and countersunk in place. The need for such special precautions, however, was unnecessary when an oxy-acetylene torch was available because, after tightening a tap rivet, the square drive pin on its countersunk head could be burned off, the head heated in place, and then hammered up to tightly fill the hole. Tap rivets were extensively used on Admiralty ships; in merchant vessels, tap rivets were widely used for the bulwark angle bar stanchions as the distance that would have to be spanned through the decking was unsuitable for through-rivets.

Rivet points

Rivet points of various kinds were used in shipbuilding. The 'hammered point' was the most easily made, because it was expeditiously clinched and required no chipping. There was little difference between it and the countersunk point with regard to strength. The rivet had to be long enough to provide sufficient material to create a well-formed, flat cone with slightly rounded sides. This point was used for nearly all internal work not requiring a flush surface. It was sometimes employed for Tank Tops and plated decks although countersunk points of full form were preferred for these areas.

The 'snap point' was not used as much because it was not as efficient. It was used only for parts not subjected to severe structural stresses, such as bulkheads, casings, etc. However, its pleasing, symmetrical appearance made it suitable for parts exposed to view such as in passenger accommodations and in the machinery spaces. To form it, the rivet point was first staved up by squarely directed hammer blows until the shank gripped in the hole, whereupon a snap tool was held upon it and struck a few heavy blows. This resulted in a smooth, polished, hemispherical point. It was not a reliable point, since instead of receiving a series of direct blows, each one staving it up more and more solidly, the energy of many of the blows were deflected through the snap tool into the surrounding plate. This was especially the case if the rivet was too short, a circumstance indicated by the marks made upon the plate by the edge of the snap tool; moreover, the point was not always concentric with the shank. Very small rivets, $^3/_8$in and less, were closed cold and, in such cases, the point was usually formed with a snap tool.

Experiments with riveted joints showed the 'countersunk point' to be the most efficient with regard to both frictional resistance and ultimate strength. These tended to result in sounder work; the countersunk portion reduced the length of the rivet shank requiring staving, thereby increasing the likelihood of the shank fully filling out the entire hole through which it passed. The point could be finished off quite flush, slightly convex, or full, like a hammered point. Those in the

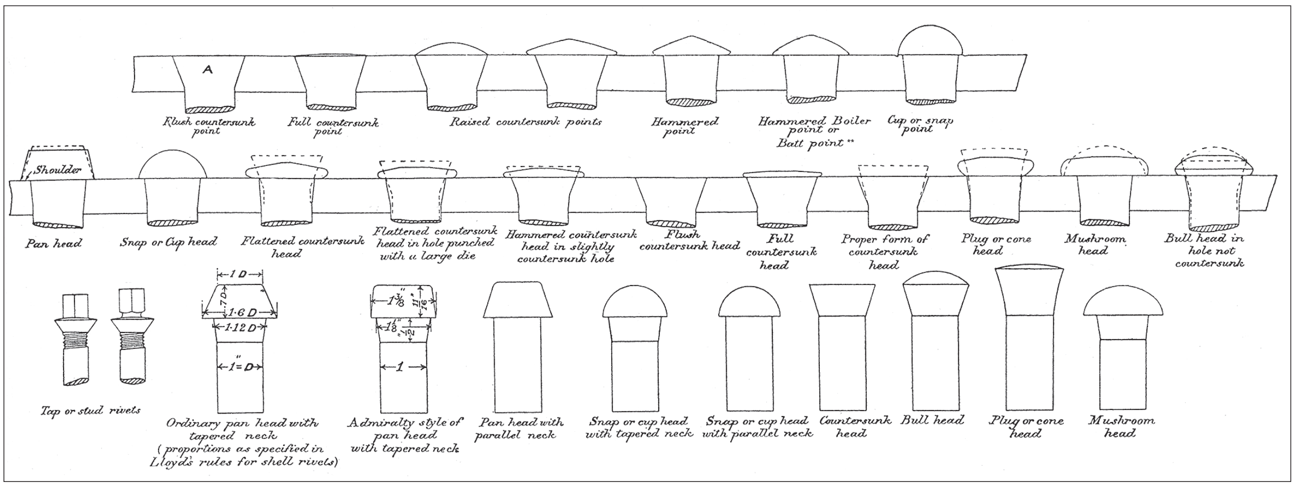

A
Flush countersunk point
Full countersunk point
Raised countersunk points
Hammered point
Hammered Boiler point or Batt point **
Cup or snap point
Shoulder
Pan head
Snap or Cup head
Flattened countersunk head
Flattened countersunk head in hole punched with a large die
Hammered countersunk head in slightly countersunk hole
Flush countersunk head
Full countersunk head
Proper form of countersunk head
Plug or cone head
Mushroom head
Bull head in hole not countersunk
1 D
·7 D
1·6 D
1·12 D
1" = D
1⅜"
11/16"
1⅛"
½"
1
Tap or stud rivets
Ordinary pan head with tapered neck (proportions as specified in Lloyd's rules for shell rivets)
Admiralty style of pan head with tapered neck
Pan head with parallel neck
Snap or cup head with tapered neck
Snap or cup head with parallel neck
Countersunk head
Bull head
Plug or cone head
Mushroom head

Fig. 2-4 **Forms of Rivets** – This figure illustrates the various types of rivet heads, shanks and points employed in iron and steel ship construction. The hammered boiler point, second from right in the top row (*), was known locally in Belfast as a 'Batt point,' and is specified in this manner on the main construction drawings.

underwater part of the shell were slightly convex, in order to provide substance for corrosion, because the rivet points were often found to corrode faster than the surrounding plate. In other areas, they could be finished off quite flush; to form countersunk points with a slight fullness was generally advantageous, but required more time and care on the part of the riveters.

The points and heads of rivets employed in attaching the shell plating to the stem bar were countersunk and were left especially full as these rivets, particularly those located at the load line and below, were exceptionally liable to corrosion. In deck and tank-top plating, the rivets usually had countersunk points and were left full in some cases, like a hammered point, which was advantageous in the case of thin plating where a flush, countersunk point would have provided insufficient resistance against the pulling apart of the joined pieces.

Rivet-hole punching

Nearly all rivet holes in the steelwork of *Titanic* were punched. Punching, not drilling, of rivet holes was the common practice in nearly all shipyards at that time. Experience gained through this period in time indicated that the shearing strength of rivets in drilled holes was less than those fitted in punched holes, due to the sharper cutting edge of the former and the fact that the rivet shank – the part between the head and point – which was perfectly cylindrical, elongated more readily, permitting a greater deformation of the point.

'Cold punching' holes into the steel after it had cooled caused microfractures in the material immediately surrounding each hole punched into the shell plating. Though this phenomenon was well known to shipbuilders and engineers of the day, it was considered to be of little cause for concern in most areas of the ship's structure; in those areas that were expected to be under constant stress, reaming, or 'rimering', of the holes to finished size was specified. In their later years of service, *Olympic* and other ships of the period were found to be prone to developing small hairline cracks around the punched rivet holes in some areas of plating. Repairs often required the fitting of doublers and the welding of some seams to strengthen the shell plating. It was not until the 1930s that drilling of all rivet holes became a requirement of most classification societies as well as a common practice in most shipyards.

In all frames, plates and bars throughout the vessel, it was of vital importance that the punching be done from the 'faying surface'. The faying surfaces were those brought to bear against each other once riveted together, as in the case of frame and reverse-angle flanges. The reason for this was that in punching a plate or bar, the action of the punch left a raised edge on the opposite side from that on which the punch entered the material. This edge was a hindrance to any other plate or bar bearing tightly against it. Additionally, and as importantly, the holes produced by punching tended to be conical in form, with the larger diameter being formed on the side opposite from which the hole was punched; punching rivet holes from the faying side guaranteed that the larger side of the hole always faced outward in both pieces being joined, where the natural countersink formed could be used to best advantage when staving up the rivets.

Rivet preparation

Prior to being inserted, the rivets were heated in small, portable hearths, placed point downwards in the fire so that the heads would remain relatively cool to avoid being flattened too much under the hammer. A perforated plate was laid on the fire, so that only the points of the rivets (each one placed in a hole) would receive the full effect of the blast. The rivets were not held in the fire for prolonged periods, as the terrific heat would thin the rivets by oxidation, seriously compromising their mechanical qualities. Some large iron rivets could be heated almost to a plastic welding temperature, but small iron ones were not heated to such high temperatures. Steel rivets, if heated to such a high temperature, would be very near the burning point, seriously compromising the strength of the rivet. For this reason, steel rivets were not worked as hot as iron rivets.

Manual riveting

A 'rivet squad' consisted of three men and one or two boys and worked with iron rivets, as this material was more malleable than steel. One boy heated the rivets; the other conveyed them to and inserted them in the hole. If there was only one boy, he would toss the rivets to the man called the 'holder-on' or 'holder-up'. While this man held the head in place using a 'holding-up' hammer of between 13 and 16lb, the other two men would clinch the point. Riveting hammers varied from 3lb to 8lb in weight, relative to the size of the rivet and its location.

The procedure of closing a rivet was as follows: the hot rivet was inserted in the hole, the holder-up struck the head a few blows to 'lay it up' so that it would bed fairly on the plate; he then 'held it up' with the hammer, placing the head of the hammer against the rivet head while the two men on the other side struck the rivet several blows in rapid succession to clinch the point. At first, the point was struck fairly, end-on, so that the shank would be staved up and fitted tightly in the hole throughout its length right up to the head; if it was a countersunk point and the rivet shank was rather long, it was then struck towards one side so as to bend it over in such a way that the surplus material not required to fill the countersink could bulge to one side and thus be chipped off while still hot. After chipping off the surplus, the rivet was allowed to stand for a few minutes until it had cooled; it then received a second series of blows, delivered with care all around the edge of the point, which caulked it and, in quality work, finished it off so smoothly as to make it difficult to discern the precise line of demarcation between rivet and plate. While waiting for one rivet to cool prior to this second set of blows, the team would use this time to apply the finishing blows to the prior inserted rivet, and – if necessary – in rimering the hole for the next rivet. To deliver the second set of blows immediately after the first would result in a rivet which, when cooled, would be loosened by the contraction in the diameter of its shank and point and by the subsequent drifting of the adjacent hole and hammering up of the rivet. After the first series of blows, the rivet point usually showed a slightly bluish temper (especially if a steel rivet), and the second series of blows, if given at the proper time, would dissipate this, leaving the finished point showing no color. In very hot weather, when the rivets cooled more slowly, it was advantageous, especially with large rivets, to delay giving the final series of blows until two others had been clinched.

While giving the final series of blows, the plate was also struck; this was done along the edge and between the rivets, to bring the faying surfaces everywhere into close contact. This was an important condition, because it would be closely checked when the work was subsequently examined and tested.[3]

Hydraulic riveting

Hydraulic riveting was superior to hand riveting in that there was little chance of unsound rivets, and the different parts, however stiff, could be forced into absolute contact thus securing a high frictional resistance. The soundness of hand-closed rivets varied with the skill of the rivet team, and even with skilled teams, some holes were not fair and the rivet shanks would not completely

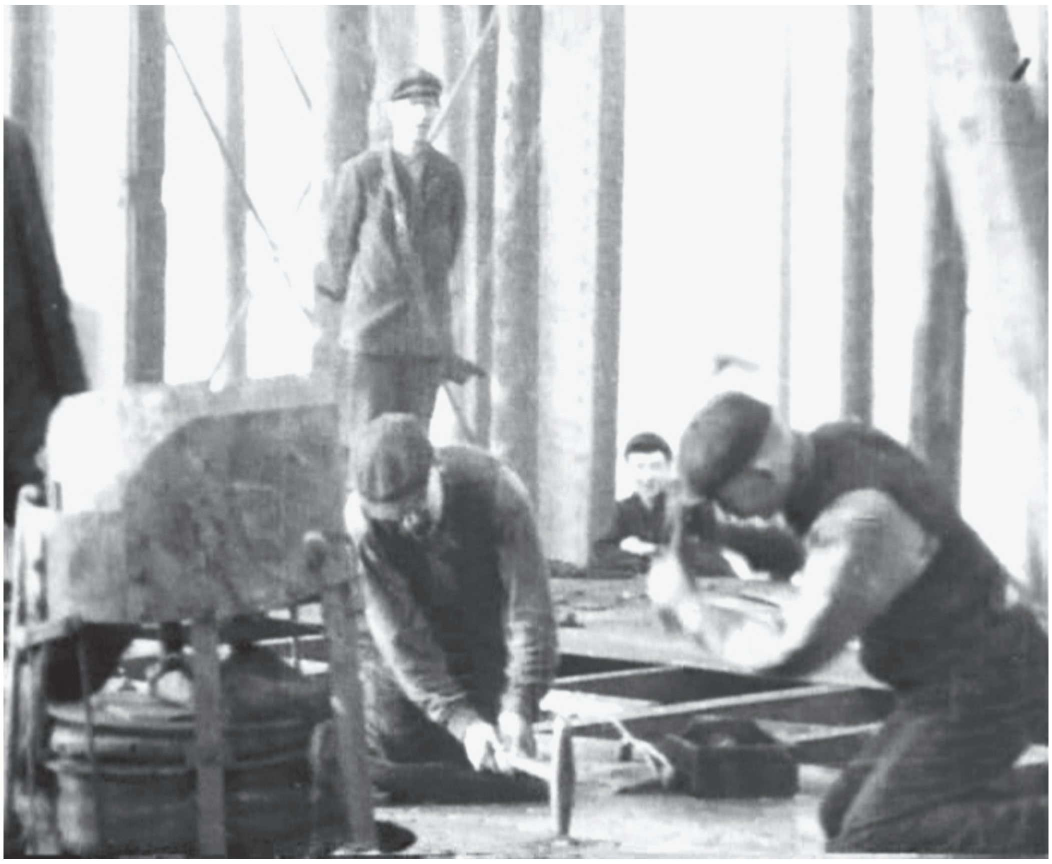


Fig. 2-5 **Hand Riveting** – In this image from a period newsreel film, two Riveters are at work on *Olympic*'s steel plating. A small furnace is just to the left. *(Robert Hahn collection)*

fill them. A rivet that was closed by hydraulic power was subjected to such intense compression that the material of its shank flowed almost like wax, with the result that even very unfair holes would be sealed fully.

The process for hydraulic riveting was as follows: the rivet head was held up by one die of the machine, while the other die, taking contact with the point, first crushed up the shank and then molded the point in its cup-shaped recess.

Any excess of material oozed out as a thin collar. In order that the shank would stave up before the point, it needed to be hotter than the point. To achieve this, the points of long rivets were chilled in water. The rivets were not to be hotter than a bright red or they would flow in so liquid a fashion that some of the shank material could be forced between the faying surfaces. This sometimes occurred when the parts to be riveted were not bolted tightly together.

Steel rivets that were cold could be closed by hydraulic power, but so much pressure was necessary that the plate, being nipped with the rivet, could also become indented. This effect would sometimes be observed in rivets by a slight bulging of the edge in way of each rivet, especially when situated near the edge of a plate or bar.

The pressure adopted in a hydraulic riveting machine varied with the class of work and the judgment of those in charge. Water pressure at the accumulator was usually about 1,500lb per square inch. Although the pressure was fixed, the actual force brought to bear on the rivets depended on the design and dimensions of the particular machine employed (i.e., the diameter of the ram and its leverage). In heavy boiler work, the rivets were usually subjected to a pressure of about 100 tons per square inch of their sectional area; a considerably smaller pressure sufficed in ship work as the plates and other structural members were much thinner.

The procedure adopted in hydraulic (machine) riveting was first to hold the parts together with a bolt in every second hole for a distance of 5 to 6ft; after the intermediate holes were brought into alignment, some ten or twelve rivets which had been heating in bulk in a small reverberatory furnace were inserted and closed, this taking little more than a minute. If the parts did not lie perfectly flush together between the rivets, the necessary contact was achieved by nipping them together with the riveting machine. In machine riveting, it was the preparatory work that took time as the rivets themselves could be closed almost as fast as they were placed in the holes. Expedition and efficiency made machine riveting preferable to hand riveting. There was, however, the risk that if done too hurriedly, the riveting machine might not be held squarely on the rivet, the result being that the shank would not be properly staved up and the point would not be concentric with the shank. Sometimes a rivet could be too short, resulting in an insufficiently staved shank or an imperfectly formed point. In heavy work such as keel riveting, the riveting machine was not to be removed until the rivet had cooled somewhat, for if released when it was still hot and soft, the parts could spring apart; by working the rivets fairly cold, the need for this delay was eliminated, especially when working with light parts. In heavy boiler work, each large rivet received a second squeeze after it had cooled. Ordinary pan-head rivets were generally used for machine work, the finished head and point being almost invariably of the snap type. If a countersunk point was required, a flat or nearly flat die was used, but as the point always projected somewhat so that it, and not the plate, received the pressure of the riveting machine, hand chipping and caulking were required to finish the rivet off. This necessity was a deterrent to the use of the riveting machine for countersunk riveting. When the sheer strake was machine-riveted, the points could be of the snap type; given their above-water location, this presented no problems.

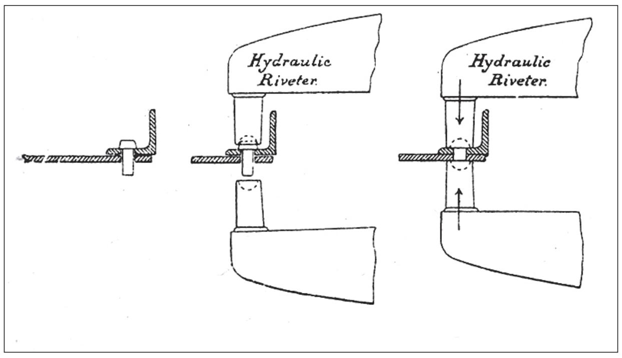


Fig. 2-6 **Hydraulic Riveting** – The action of a hydraulic riveting machine.

Hydraulic riveting was adopted to some extent in all large shipyards; however, it was not always found to be advantageous in regard to expedition and economy, and although riveting machines were available, they were not always employed. Their use was generally confined to the riveting together of the frames, reverse bars, and floors, or the component parts of built-up beams, deck girders, bracket plates, tank margin lugs to margin plates, etc., as these parts existed in large numbers. They could be brought to the riveting machine, bolted together and riveted without delay in wholesale fashion. Even small riveting machines weighed upwards of half a ton and required pipe connections for a hydraulic supply; they were located in a convenient spot where they could be suspended from a small trolley or runner, which traveled out and in on the horizontal arm of a crane, so that the riveting machine could reach every point of the area swept by the latter.

In the yard of Harland & Wolff, an extensive and elaborate hydraulic installation was provided which made it possible to machine-rivet much of the hull in place. The riveting machines were suspended from traveling hoists suspended from the gantry above, the hoists traveling fore and aft on permanently fitted overhead rails. These hoists were also used for lifting and assembling the various parts of the structure.

Hydraulic riveting machines varied in design according to the particular make and the nature of the work they were intended to execute. Portable riveting machines were first used around 1871, with numerous mechanical refinements being introduced in the years that followed. The hydraulic elevating mechanism and tilting gear facilitated moving and adjusting the otherwise cumbersome machine and the increased efficiency further promoted the use of riveting machines. Some were arranged with two different powers, so that a suitably small pressure could be brought to bear when closing small rivets, thus avoiding useless expenditure of pumping power at the accumulator. Riveting machines for heavy work were sometimes arranged with a sleeve around the snap die, which nipped the joint in advance and held the parts together during the closing of the rivet.

The firm of Fielding & Platt manufactured the riveting machines used by Harland Wolff. They were of the direct acting type and had the appearance of a huge 'C' clamp with an inward gap of 7ft. The riveting machines exerted a pressure of 40 tons with a working hydraulic pressure of 800lb per square inch. The machines were lifted into place with the use of a special tackle and quadrant hanger attached to one of the overhead hoists on the gantry. The main body of the riveting machine was a single piece of Siemens cast steel and the cylinders were bored and fitted with a gunmetal liner throughout their working length.

Contrary to popular belief, *Titanic*'s hull did contain a large number of steel rivets. Harland & Wolff's specifications for steel rivets in *Titanic*'s plating were indicated by a note on the Shell Plating plan which reads as follows:

> W, Y & Z strakes to be hydraulic riveted as shown by red line.
> Hydraulic riveting also for full length of wing tank as shown on plan.
> Keel plate to be hydraulic as far forward & aft as possible.
> 1¼in steel rivets in keel & in 'B' strake as shown by yellow line.
> Remainder of hydraulic riveting 11/8 steel rivets.

Steel rivets were also specified in the stringer plates on several deck iron plans in areas where higher than average compression and shearing loads were expected. If the area of *Titanic*'s hull actually impacted by the iceberg had been joined with steel rivets rather than with iron, there is a possibility, albeit slight, that the damage sustained might have been reduced by some small amount.

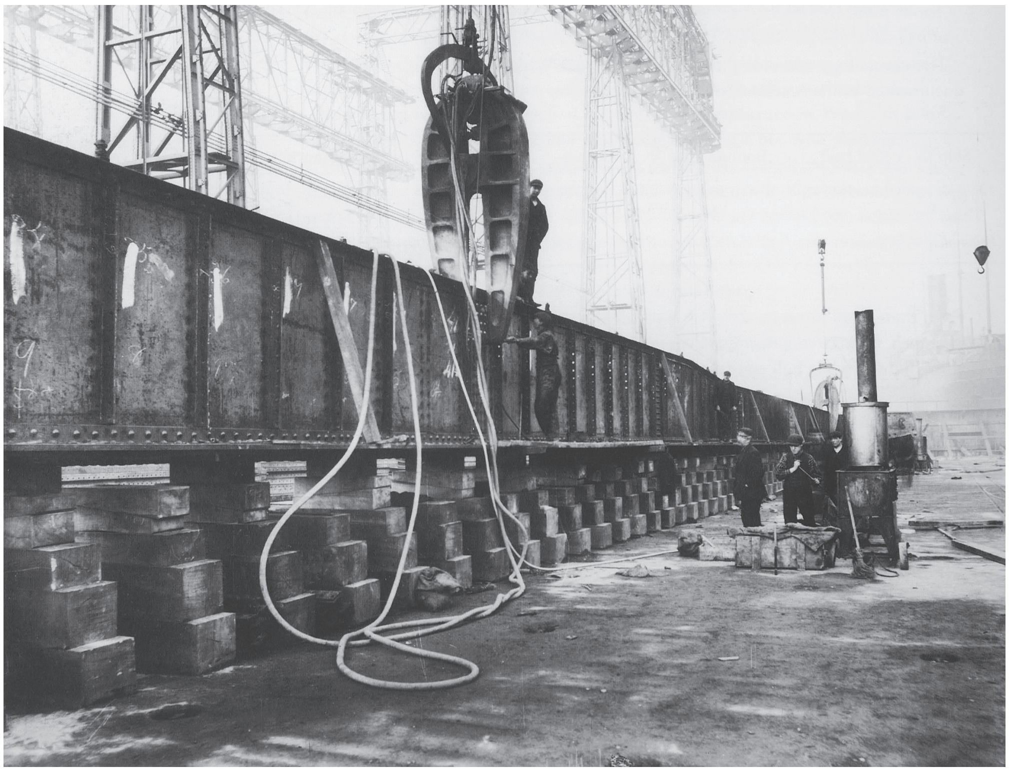


Fig. 2-7 **Hydraulic Riveter at Work on the Vertical Keel Plate of *Olympic*.** (The Shipbuilder/*Authors' collection)*

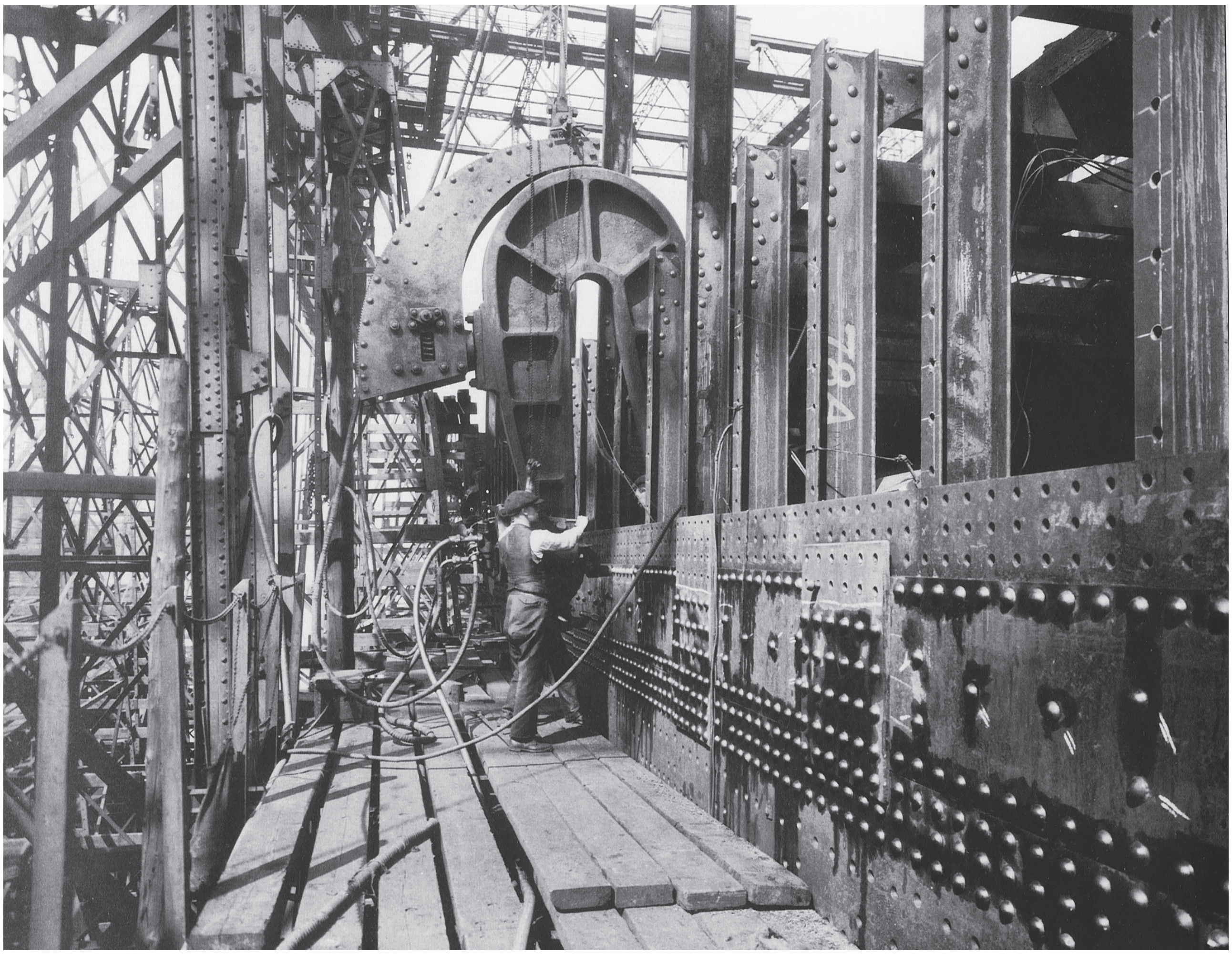


Fig. 2-8 **Hydraulic Riveter at Work Along the Sheer Strakes of *Olympic*.** (Engineering/*Authors' collection*)

Notes

1. The three million rivets specified in *The Shipbuilder* accounts for only those rivets holding together the structural components of the hull and superstructure; many more rivets were used in fabricating the boilers, machinery, appliances and fittings of the completed vessel.
2. 'Chipping' was the process of removing excess material from rivet points, plate edges, the flanges of structural shapes, etc., and was originally performed using a hammer and a sharp, chisel-like tool. By the time *Titanic* was being built, most chipping was done with a pneumatic impact tool fitted with special bits designed for this purpose.
3. Riveting was negatively influenced by wet weather. When water got between the faying surfaces of the joint, it chilled the hot rivet shank and the film of steam which formed alongside prevented close contact of the faying surfaces.

Chapter 3

The Keel, Floors and Double Bottom

Titanic was constructed with a 'double bottom' in which the lowest part of the hull was formed not by a single layer of steel plating, but by a heavily reinforced structure with the vertical keel as its backbone. With the outer bottom plating forming the 'skin' of the ship, the inner bottom plating formed the 'Tank Top', so named because the resultant structure, together with its longitudinal girders and transverse members, formed a series of tanks. These tanks were used to carry water for ballast and boiler feed. In addition to the carriage of water, the double bottom added to the safety of the ship. As the Tank Top formed a second skin, it could save the ship from sinking if the ship struck a sunken obstruction or ran aground. Even with the outer bottom torn open, the watertight inner bottom would limit the flooding to the double-bottom space and prevent the entry of water into the holds or machinery spaces. The depth of the double bottom was determined by the depth adopted for the vertical keel but had to be, at a minimum, sufficient for ready access to all parts of the double-bottom space for construction and maintenance.

Keel

Titanic's keel was laid on March 31, 1909,[1] in Slip No.3 of Harland & Wolff's Queen's Island Shipyard at Belfast. *Titanic*'s keel was of the 'flat-plate' design, formed by a single thickness of plating $^{30}/_{20}$in thick[2] and reducing to $^{24}/_{20}$in toward the ends. The keel plate was 52in wide at its broadest point and was strengthened below by a flat slab bar 19½in wide by 3in thick. The purpose of this flat slab bar, called a 'rubbing strip', was to protect the flat-plate keel from being damaged if the vessel should run aground. It also protected the keel plate during dry docking.

In riveted hull construction a flat-plate keel resembled an ordinary strake of outside shell plating, the difference being that it was of much greater thickness than the adjacent strakes. This was necessary not only because of the wear and tear to which this plate was often subjected, but also because, in conjunction with the vertical center keel plate, or 'vertical keel', which stood upon it and to which it was attached, it was a considerable factor in the longitudinal strength of the hull.

The vertical keel, which was attached to the keel plate on end by continuous double angle bars, formed the center of the double bottom and was $^{20}/_{20}$in thick, tapering to $^{14}/_{20}$in thick towards the ends. The height of the vertical keel was 63in, increasing in height to 75in beneath the Reciprocating Engine Room. The angle bars used to make the connection to the vertical keel were of a size and thickness approaching and, in some instance equal to, the thickness of the plates to be connected.

The keel plates were laid upon wooden keel blocks on the slip at the earliest stage of construction, and straight lines were drawn along the middle of each piece of plate, coinciding with a line stretched along over the blocks to designate the centerline of the ship. Once correctly adjusted, the plates were temporarily secured while the vertical keel was being fitted.

The holes for the rivets connecting the keel plate to the frames, keel plate angles, garboard plates and butt straps were carefully set off and punched before the plates were laid upon the blocks. The length of each plate was made as an exact multiple of the frame spacing. Doing so eliminated any difficulty in accurately arranging the holes for the rivets so that they could be transferred from a template suitable for use on a major portion of the vessel's length.

Floors

As with all steel ships, the bottom structure of *Titanic* was of great importance to the overall design as it acted as the lower flange of the giant box girder formed by the hull. In conjunction with the keel, the bottom resisted the longitudinal stresses produced by the uneven support of the hull girder by the crests and hollows of actual waves at sea. Like the keel itself, the entire bottom was

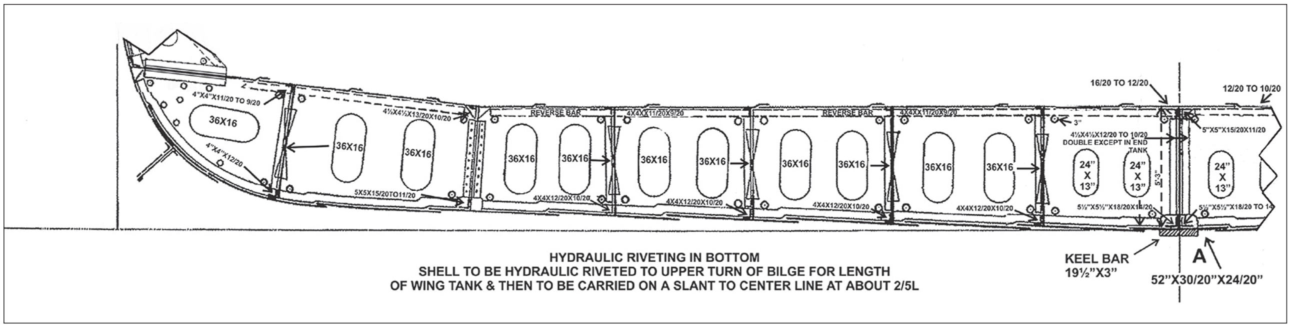

4"X4"X11/20 TO 9/20
36X16
4"X4"X12/20
4½X4½X13/20X10/20
5X5X15/20TO11/20
REVERSE BAR
4X4XX11/20X9/20
4X4X12/20X10/20
24" X 13"
16/20 TO 12/20
12/20 TO 10/20
3"
4½X4½X12/20 TO 10/20
DOUBLE EXCEPT IN END TANK
5'3"
5"X5"X15/20X11/20
5½"X5½"X18/20X14/20
5½"X5½"X18/20 TO 14
HYDRAULIC RIVETING IN BOTTOM
SHELL TO BE HYDRAULIC RIVETED TO UPPER TURN OF BILGE FOR LENGTH
OF WING TANK & THEN TO BE CARRIED ON A SLANT TO CENTER LINE AT ABOUT 2/5L
KEEL BAR
19½"X3"
A
52"X30/20"X24/20"

Fig. 3-1 **Keel Plate and Double Bottom** – A detail from the midship section showing *Titanic*'s keel and floor design. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

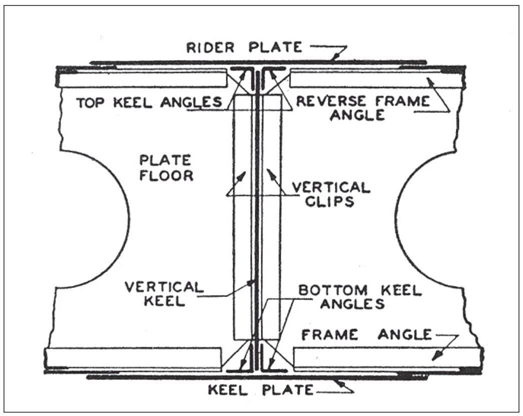

RIDER PLATE
TOP KEEL ANGLES
REVERSE FRAME ANGLE
PLATE FLOOR
VERTICAL CLIPS
VERTICAL KEEL
BOTTOM KEEL ANGLES
FRAME ANGLE
KEEL PLATE

Fig. 3-2 **Keel Structure**. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

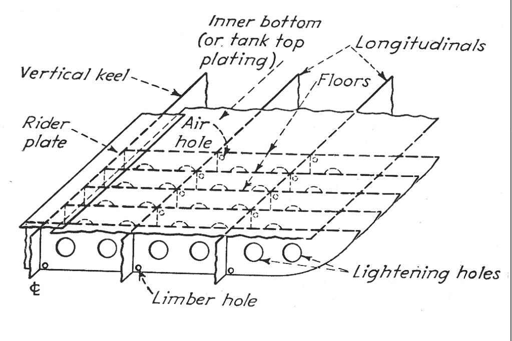

Inner bottom (or tank top plating)
Longitudinals
Vertical keel
Floors
Rider plate
Air hole
Lightening holes
℄
Limber hole

Fig. 3-3 **Structural Elements of the Double Bottom** – A simplified illustration identifying the basic structural elements which comprise the double bottom of a steel ship.

stiff enough to withstand the concentrated pressures of dry docking and grounding and was strong enough to support the weight of the machinery and cargo. The additional strength and stiffness required was obtained by deepening the transverse framing across the bottom of the hull to form what were known as 'floors'. (A ship's floors are not horizontal as in a building; rather, they are vertical transverse structural members which extend across the ship from bilge to bilge.)

The floors in *Titanic*'s double bottom were placed at every frame; generally, they were made of steel plates 15/20in thick, reducing to 11/20in towards the ends of the ship. The floors of the wing tanks, situated outside the margin plates, were of slightly lighter material, ranging in thickness from 13/20in amidships, reducing to 11/20in towards the ends of the vessel. Extra strength and rigidity in the ship's bottom was required under the machinery spaces due to the concentrated loads found there, as well as the heavy stress and vibration set up by the engines and the increased liability to corrosion due to heat and moisture in these compartments. To compensate for this, the thickness of the floors was increased to 17/20in in these areas.

As in all structural design, the effectiveness of the structure depended upon the additional support provided by auxiliary structural members. These auxiliary structures consisted of widely spaced longitudinals that kept the floors from folding over, or 'tripping', in a fore-and-aft direction. The floors were stopped at the continuous vertical keel, to which they were connected by angle bars; the longitudinal girders were fitted intercostally[3] between the solid plate floors in much the same manner.

A significant amount of weight was saved by cutting lightening holes along the neutral axis of the non-watertight solid floors, except at intervals where there where no holes cut in order to form separate ballast tanks. These holes were indispensable for access in the construction and maintenance of the double bottom. A thick floor plate, when lightened properly, was stiffer and more durable against corrosion than a thinner plate without any lightening holes. The lightening holes were oval in shape and were generally 36in x 16in, except in the floors immediately to either side of the vertical keel, where they were reduced in size to 24in x 13in.

Inner bottom plating

The inner bottom[4] plating was arranged in fore-and-aft strakes, with the adjacent butts shifted or placed in different frame spaces so as to avoid lines of weakness due to any inefficiency of the riveted joints. The strakes progressed outward from the centerline strake, called the 'Tank Top rider plate', to the outer strake on each side. The rider plate was heavier than the rest of the inner bottom and formed the top flange of the centerline keel girder. Generally, the inner bottom plating was lighter than the bottom shell plating but was increased in thickness in the engine and boiler rooms to allow for corrosion and the weight of machinery. Access holes, or 'manholes', oval in shape, were fitted within the plating at intervals to allow ingress to service the tanks in the double bottom. Normally, a watertight cover plate was bolted in place to close each manhole.

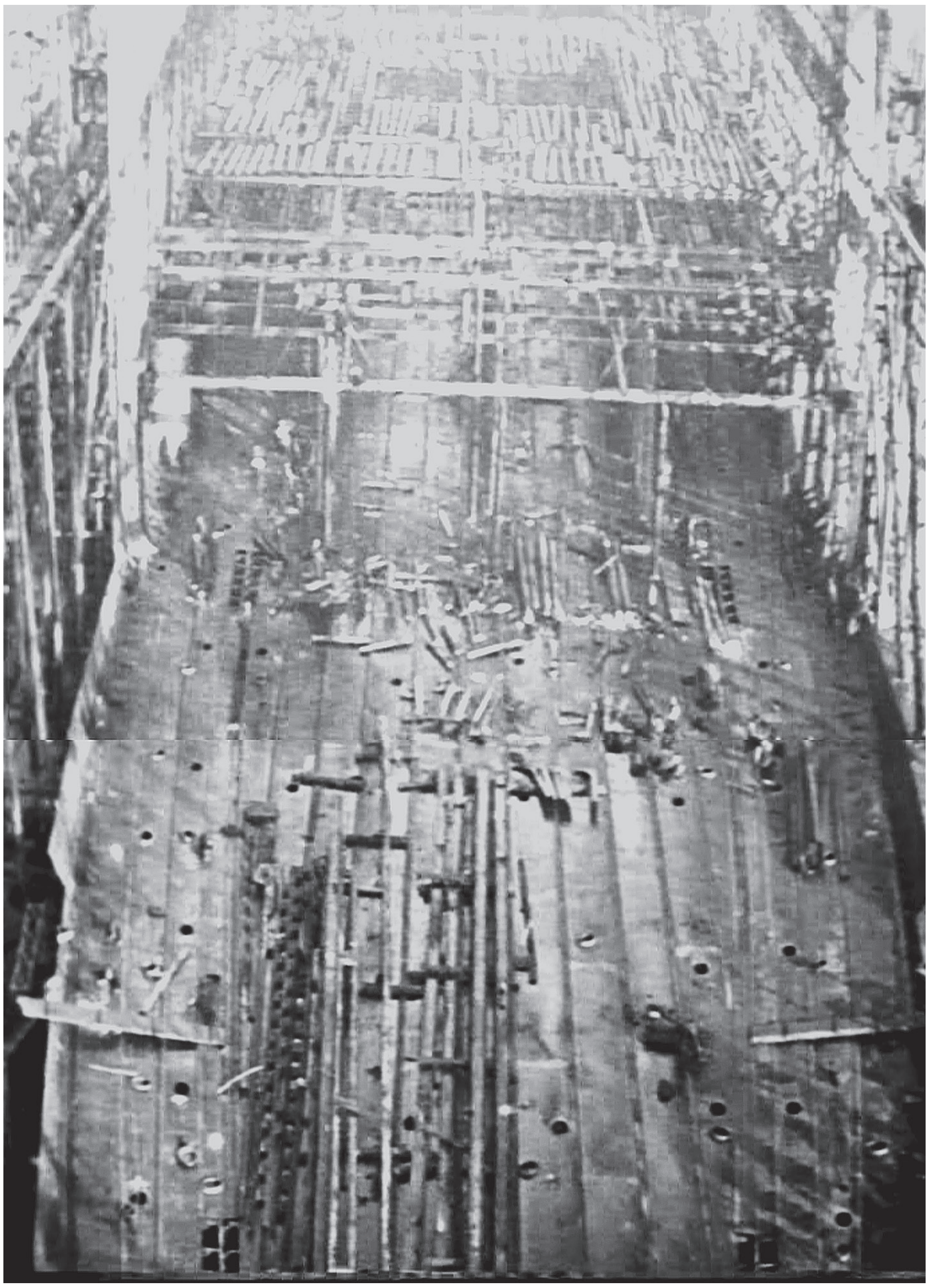


Fig. 3-4 **Manholes** – A mosaic assembled from motion picture footage showing *Olympic*'s Tank Top from the top of the gantry. Holes in the plating are manholes and drain pot cutouts. *(From an original newsreel film/Robert Hahn collection)*

In the ends of the ship, where the 'wings' at the turn of the bilge were open across the top, the inner bottom plating, along with the double bottom, ended just inboard of the turn of the bilge. Along both sides in these areas, the outer strake was connected to a steeply angled line of plating set approximately perpendicular to the molded form of the shell plating; this line of plating was called the 'margin plate'. The margin plates, which were attached to the ends of the floors through double angles, and to the inner bottom and shell plating through continuous angles, formed the watertight outer boundary of the double bottom along each side; because of this, they were also referred to as the 'tank margins'.

On large vessels like *Titanic*, in addition to the double bottom tanks flanking the keel, 'wing tanks' were fitted amidships along both sides outside (above) the margin plate. In order to form the tops of the wing tanks, the inner bottom plating in way of these tanks was angled upwards slightly and carried out to the shell plating just above the turn of the bilge. Here, it was connected to the shell through a continuous angle bar which was caulked watertight along both edges.

Cellular double bottom

The term 'cellular' was derived from the fact that the double-bottom space was divided into rectangular cells by the floors and longitudinals. These members acted as deep web frames that resisted and distributed the upward push of the water on the ship's bottom.

Titanic's cellular double bottom, inclusive of the wing tanks, extended out to the ship's sides with floors on every frame. Because the height of the double bottom corresponded to the vertical keel, it was also 63in deep at the centerline, increasing to 75in in the Reciprocating Engine Room, taking up the space between the keel and the Tank Top. The double bottom was divided transversely into four longitudinal sections by fitting a longitudinal margin plate approximately 30ft outboard of either side of the watertight vertical keel amidships, and running approximately parallel to the molded form of the hull at the level of the Tank Top. The two sections immediately adjacent to the keel ran nearly the full length of the hull, and were sealed off at their forward and after ends by watertight floors at frames 134F and 125A, respectively. The two longitudinal sections outside the margin plates occupied a space running from frames 78F to 72A. These four longitudinal sections were further subdivided by watertight transverse floors into individual tanks. The inner sections contained fifteen tanks arranged symmetrically about the vertical keel, with all but the two end tanks – Nos 1 and 15 – subdivided by the vertical keel into port and starboard tanks. The two outer sections were subdivided into eight wing tanks per side, occupying the space between the margin plates and the intersection of the inner bottom plating with the shell plating. The subdivision of the double bottom

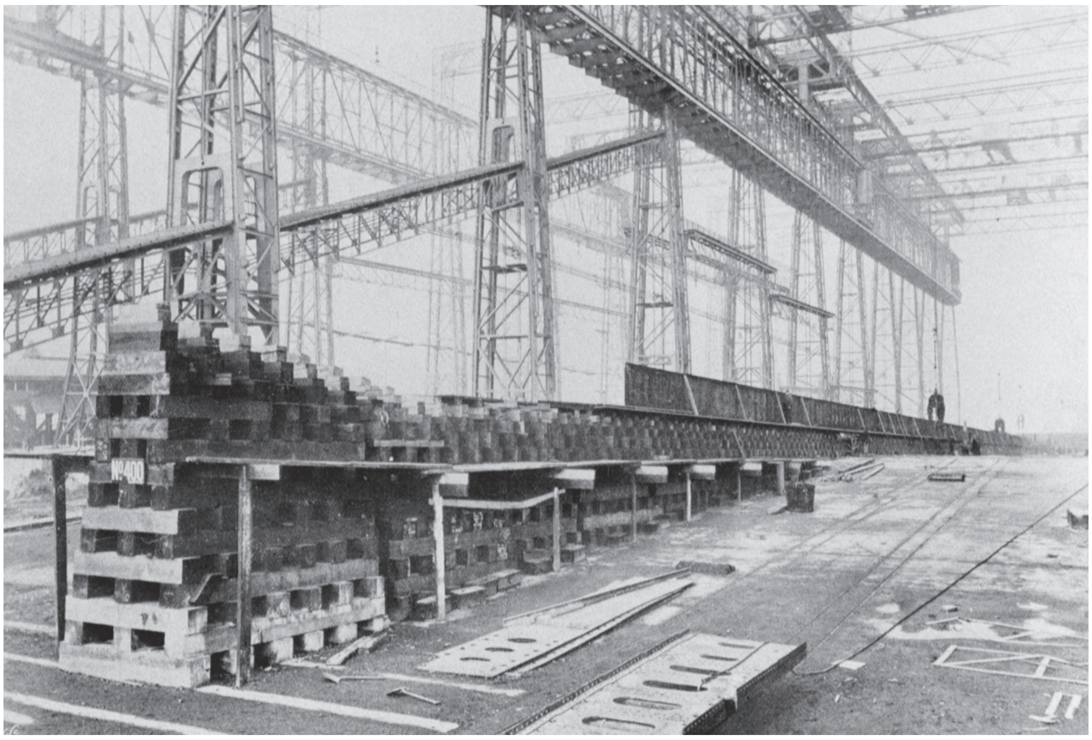


Fig. 3-5 **Keel and Vertical Keel Plate** – This image, taken on February 18, 1909, is looking aft along *Olympic*'s keel and vertical keel plate. (The Engineer/*Authors' collection)*

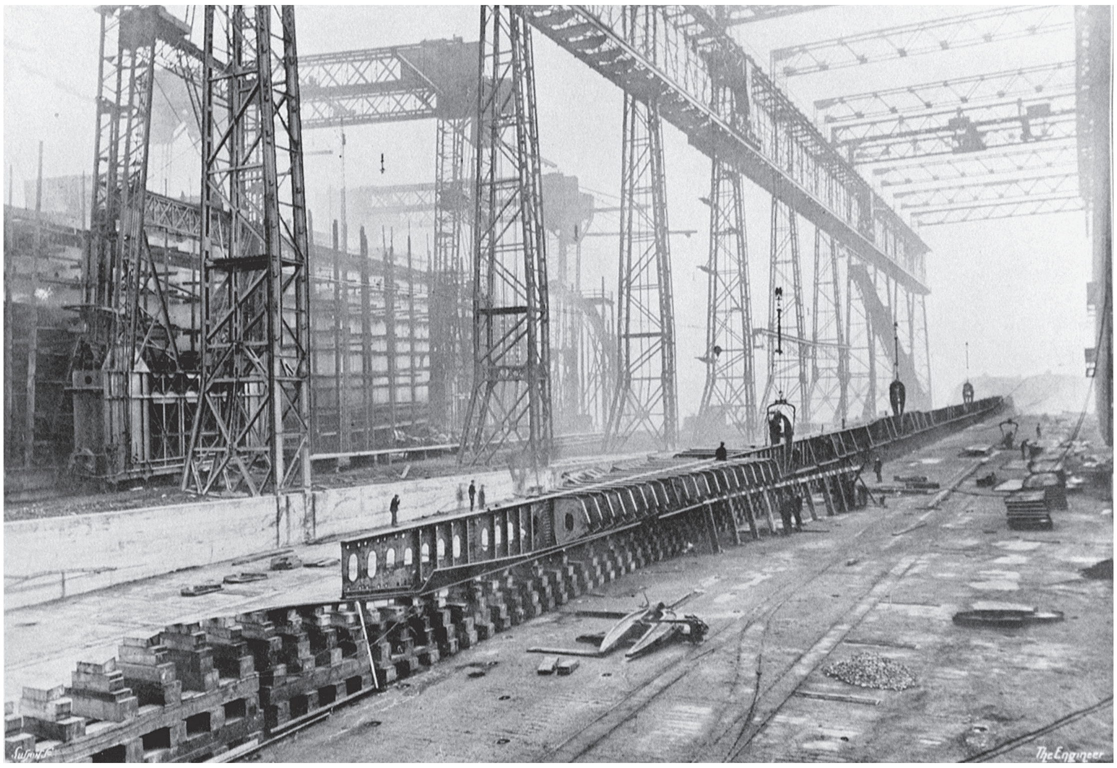


Fig. 3-6 **Vertical Keel Plate and Floors** – Looking forward along *Olympic*'s vertical keel plate on the same date as the previous image, with hydraulic riveting machines being used to attach the inboard floor plates. *(*The Engineer*/ Authors' collection)*

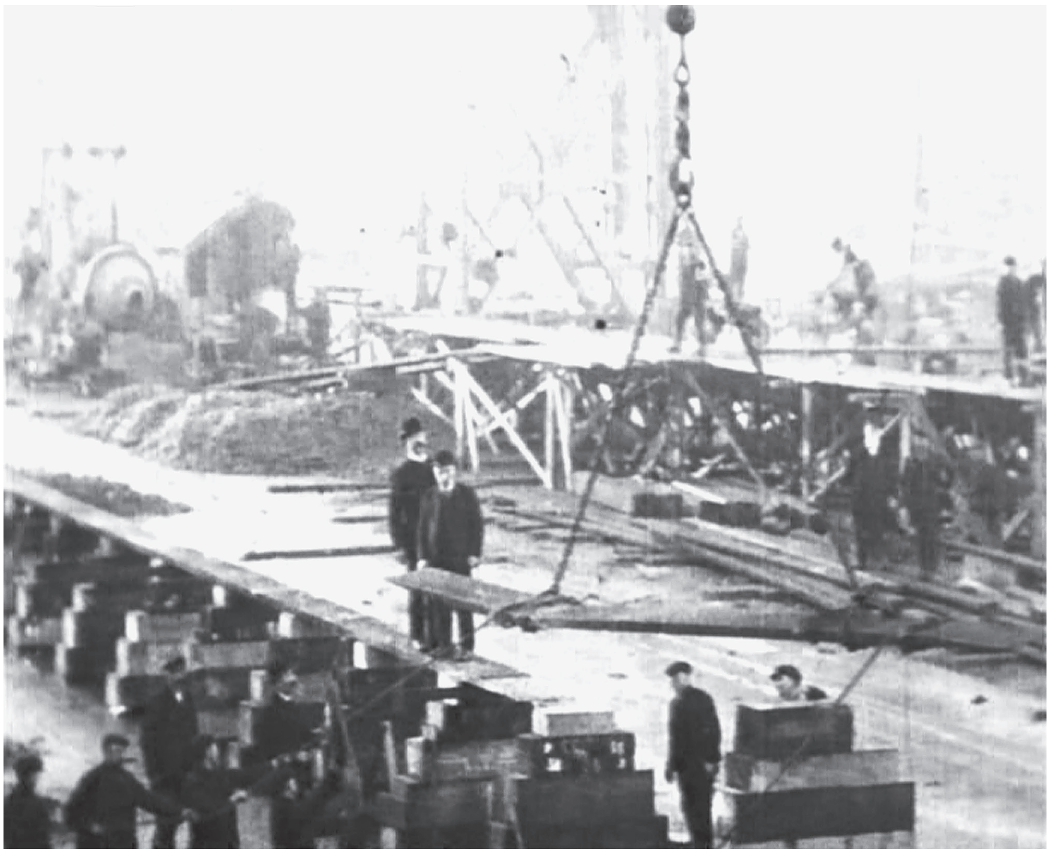


Fig. 3-7 **Laying of a Keel Plate** – The aftermost part of the 3in x 19½in keel bar, located at the transition point where the keel 'kicks up' and connects to the stern frame. *(From an original newsreel film/Robert Hahn collection)*

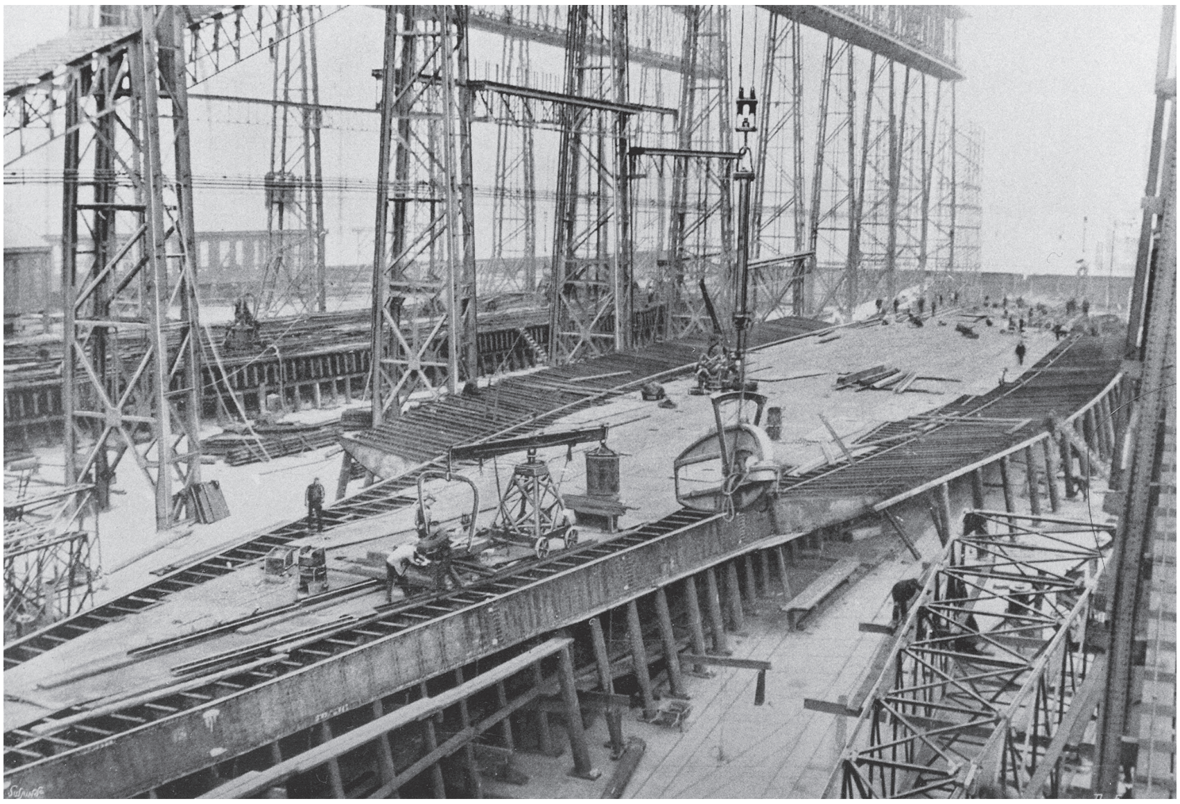


Fig. 3-8 **Tank Top and Wing Floors Looking Aft** – A view of the partially plated Tank Top and wing tank floors of *Olympic*, taken on July 2, 1909. *Titanic* is in the background. Notice the large hydraulic riveting machine suspended from overhead. *(*The Engineer*/Authors' collection)*

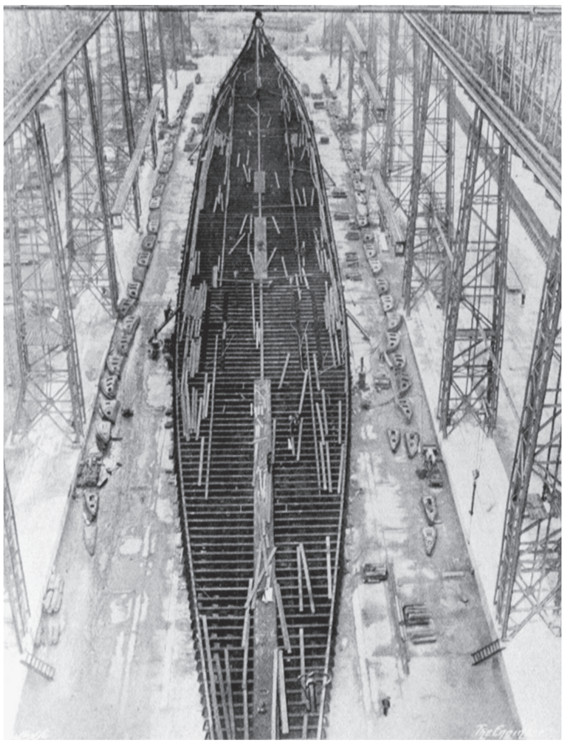


Fig. 3-9 **View From Gantry Looking Forward** – In this overhead view of *Olympic* under construction, the vertical keel, floors and longitudinal framing are all clearly visible within the perimeter created by the tank margins. The wing tank floors, awaiting installation, lay stacked in groups along both sides. *(*The Engineer*/ Authors' collection)*

into separate tanks added to the stability of the ship, as it would prevent the shifting of large volumes of water that might otherwise occur in a lesser number of larger tanks extending the full length or breadth of the hull. The total water-ballast capacity (including fresh water and boiler feed-water) was 5,754 tons, of which 190 tons were in the Fore Peak Tank and 115 tons in the Aft Peak Tank.

There were four intercostal girders amidships on each side between the vertical keel and the margin plate, the margin plate being considered a fifth girder. A sixth intercostal girder per side was fitted between the margin plate and the turn of the bilge throughout the length of the wing tanks. The thickness of these girders was generally the same thickness employed in the transverse floor plates along their respective lengths. Additional intercostal girders were added under the machinery spaces where needed for strength.

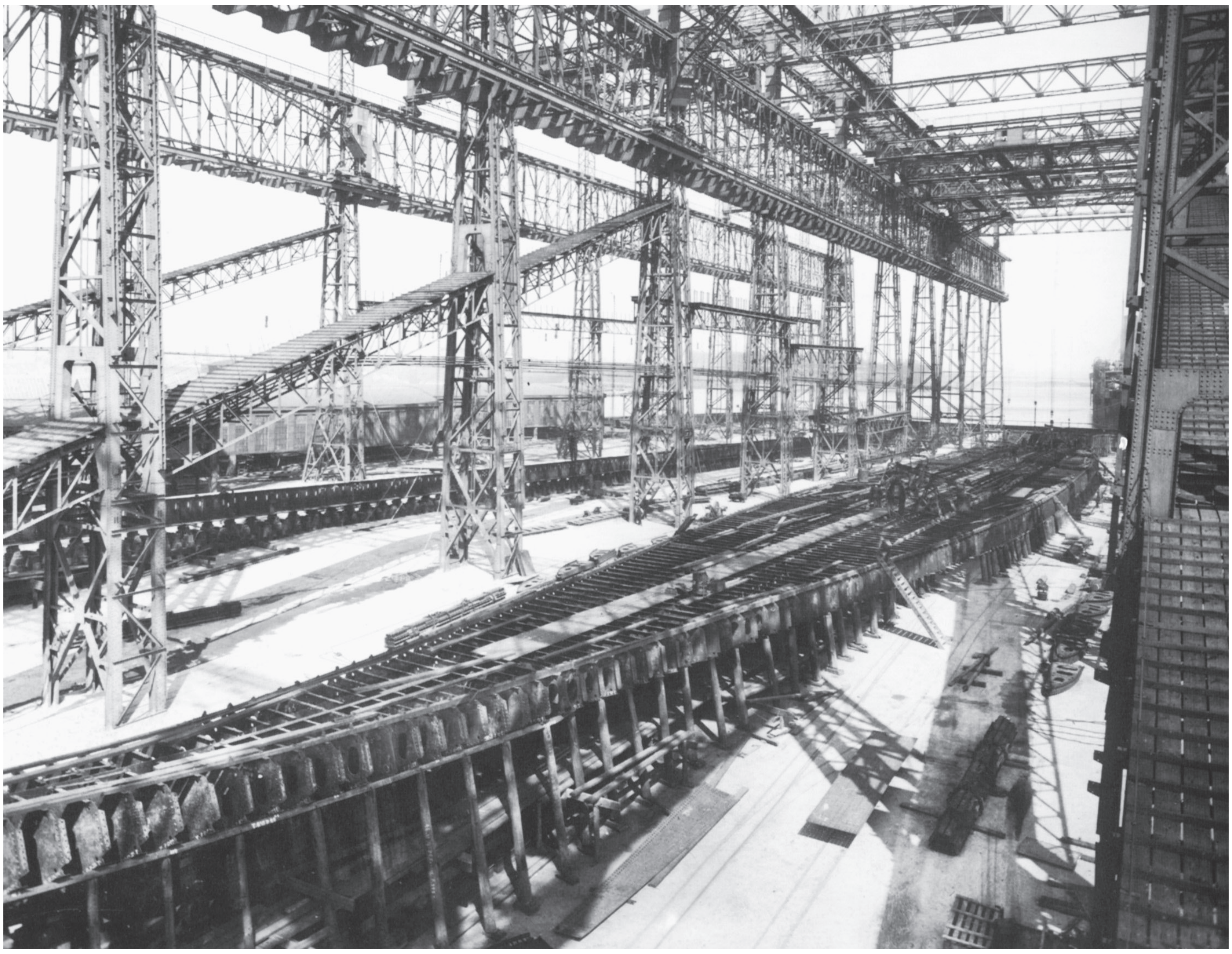


Fig. 3-10 **Tank Top of *Olympic* Looking Aft** – *Olympic*'s Tank Top is in the foreground; work proceeds on *Titanic* on the adjacent slip. (The Engineer/*Authors' collection)*

Notes

1. The date commonly referred to in most publications and in Harland & Wolff's own 'List of Particulars' is March 31, 1909; however, March 22, 1909 is the date recorded in the Harland & Wolff records held by the Public Records Office of Northern Ireland, document number D2805/Ship/3.
2. The thickness of steel plate was normally specified in twentieths of an inch.
3. An intercostal structural member was one that was made in separate parts and fitted between successive floors, frames, and beams.
4. The terms 'double bottom' and 'inner bottom' are not synonymous or interchangeable because each applies to a different part of the ship's structure. The double bottom is the series of compartments formed between the inner and outer bottoms. The inner bottom was merely the plating forming the top of these compartments. As these compartments were used to hold water for ballast, boiler feed make-up and other purposes, the inner bottom was known as the 'Tank Top'. This effectively formed the lowest deck of the ship.

Chapter 4

Frames, Beams and Pillars

The frame of a ship may be considered the skeleton of the vessel. Next to the keel, the transverse frames are the most fundamental part of a ship's structure; extending to the top of the vessel in a transverse plane, they define the shape of the hull at the point they are fitted and provide the place of attachment for all of the shell plating. Frames could be formed from nearly any of the rolled bar shapes available, although the shapes most commonly employed in framing ships of riveted construction were those of channel, plain angle, bulb-angle, T-bar and T-bulb-bar section. Frames formed from any of these bars alone were referred to as 'solid frames'. Frames constructed by riveting together any of these sections in combination with one another, and also in combination with steel plates, were called 'built frames'. The two most common forms of built frames were the angle frame and reverse frame, and the channel frame and reverse frame. In both instances, the reverse frame was formed by an angle bar riveted to the frame with its heel along the inner toe or flange of the frame, and with its fore-and-aft flange oriented in the opposite direction to the frame flanges. These terms will be more readily understood by referring to the illustrations provided with this chapter.

Spacing and identification of frames

The midship center of the hull between perpendiculars was not numbered and rested between the frames numbered 1F and 1A. The frames then progressed fore and aft from amidships, with the letter suffix denoting whether the numbered location was forward or aft of the midship center. The aftmost numbered frame was the transom frame, 148A, located at the forward side of the stern post. The foremost numbered frame, 156F, was located approximately 1ft 6in aft of the point where the Upper Deck (E) intersected the forward edge of the stem, the point which determined the position of the 'forward perpendicular'.

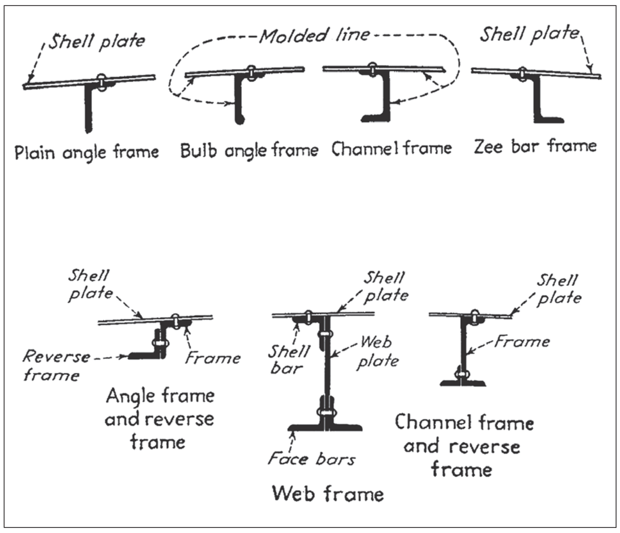


Fig. 4-1 **Framing Types** – An illustration depicting the common types of transverse framing used in the construction of riveted ship. Top row: solid frames; bottom row: built frames. *(Scott Andrews collection)*

In order to preserve the transverse or athwartship form of *Titanic* under all the conditions of stress to which she would be subjected, frames were placed at intervals of from 24 to 36in apart, the spacing being reduced at the ends of the hull. The frames were of channel section 10in wide, excluding the extreme ends where built-up angle frames and reverse frames were adopted. The reduction of distance between the frames at the forward and after ends of the ship was intended to add extra strength to areas exposed to higher stresses. For example, it was not unusual for ships which operated on the same route year round to have to force their way through 3 to 4in of ice while entering or departing New York Harbor in the winter season.

The particulars of the frame spacing were as follows:

Frames	**Spacing**
156 to 134 Forward	24in
134 to 119 Forward	27in
119 to 107 Forward	30in
107 to 95 Forward	33in

95 Forward to amidships	36in
amidships to 111 Aft	36in
111 to 121 Aft	33in
121 to 133 Aft	30in
133 to 148 Aft	27in

Vertical transverse frames: design and fabrication

The transverse framing crossed the longitudinal framework at right angles and afforded transverse, or athwartship, strength. This framing employed all of the various rolled bar shapes and combinations of these shapes. When all of the frames were in place, the whole was then covered by a skin in the form of the shell plating and decks were added, both of which not only stiffened and strengthened the skeleton or framework, but added enormously to the total strength of the ship.

The frames extended continuously from the Tank Top to the stringer plates of the Bridge (B), Poop, and Forecastle Decks. Those extending to the Bridge Deck (B) had an average height of 66ft and weighed nearly one ton each. The frames extending from the keel up to the height of the Tank Top at the turn of the bilge were formed by angle bars of relatively thin section that had been machine-joggled and then riveted to the transverse tank floors. Since the shell strakes in this area were arranged clinker fashion, the joggled angle-bar frames eliminated the need for the troublesome tapered packing pieces previously used to fill the wedge-shaped spaces usually found between the frames and plates in this method of plating. This resulted in a considerable saving in weight and contributed to a superior level of workmanship.

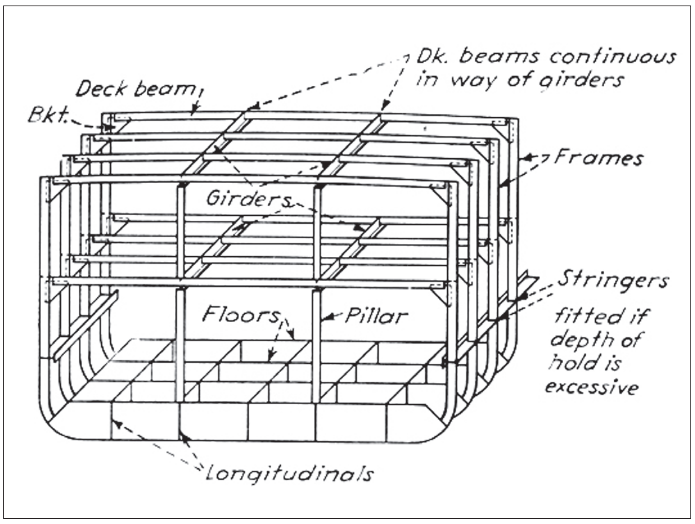

Dk. beams continuous in way of girders
Deck beam
Bkt.
Frames
Girders
Stringers
fitted if depth of hold is excessive
Floors
Pillar
Longitudinals

Fig. 4-2 **Structural Elements of the Transverse Framing System** – A simplified illustration identifying the basic structural elements which typically comprise the transverse framing system of a steel ship.

The two uppermost decks forming *Titanic*'s superstructure were built to ensure a high degree of rigidity. At the sides they were supported on built-up frames in line with the hull frames, but at a much wider interval of every third frame.

The deckhouses were specially stiffened by channel section steel fitted to the framework, and where the public rooms pierced the decks, as on the Boat Deck, heavy brackets were introduced to increase the resistance to racking forces when the ship was steaming through a heavy seaway.

The frames were manufactured as straight bars cut to rough oversized length. They were bent to the required shape and then trimmed to proper size in the shipyard by the frame benders. The initial step in preparing the frame bars was to punch all the necessary rivet holes before it was bent to its required shape. The rivets connecting the frames to the reverse frames were spaced at a pitch of 6⅛ diameters apart;[1] those connecting the frame bars to the shell were spaced from as little as 4 diameters to as great as 7⅛ diameters apart, depending on the size and location of these rivets and the thickness of the materials being connected.

The punching process accommodated the rivet holes for the turn of the bilge (which were apt to elongate and partially close up, owing to the amount of bending which took place) and the rivet holes in way of all the edge laps or landings of the strakes of outside shell plating. Because only one rivet was put through the frame in way of the shell landings (except in the case of joggled plating[2]) so as not to unduly weaken the frame, it was essential that the hole be perfectly fair in order to ensure the best workmanship.

The positions of the shell landings were obtained from the scrive board by bending a light wooden strip around the particular frame being dealt with and marking the laps upon it. On allowing the strip to spring straight again, it was laid upon the straight frame bar and the position of the laps transferred. The space between the rivet hole in one lap and the rivet hole in the next lap was divided off into equal spaces representing, as nearly as possible, about 7 or 8 diameters of the rivet.

The holes for beam knees were left unpunched with the exception of one hole. In fairing up the beam or sheer line, one or more beams may have needed slight raising or lowering after being temporarily placed in position. The single hole punched in the knee was also necessary in order to attach the tackle for hoisting the beam up into place.

The next step in preparing the frames was to bend them to shape. Within the same shed in which the scrive

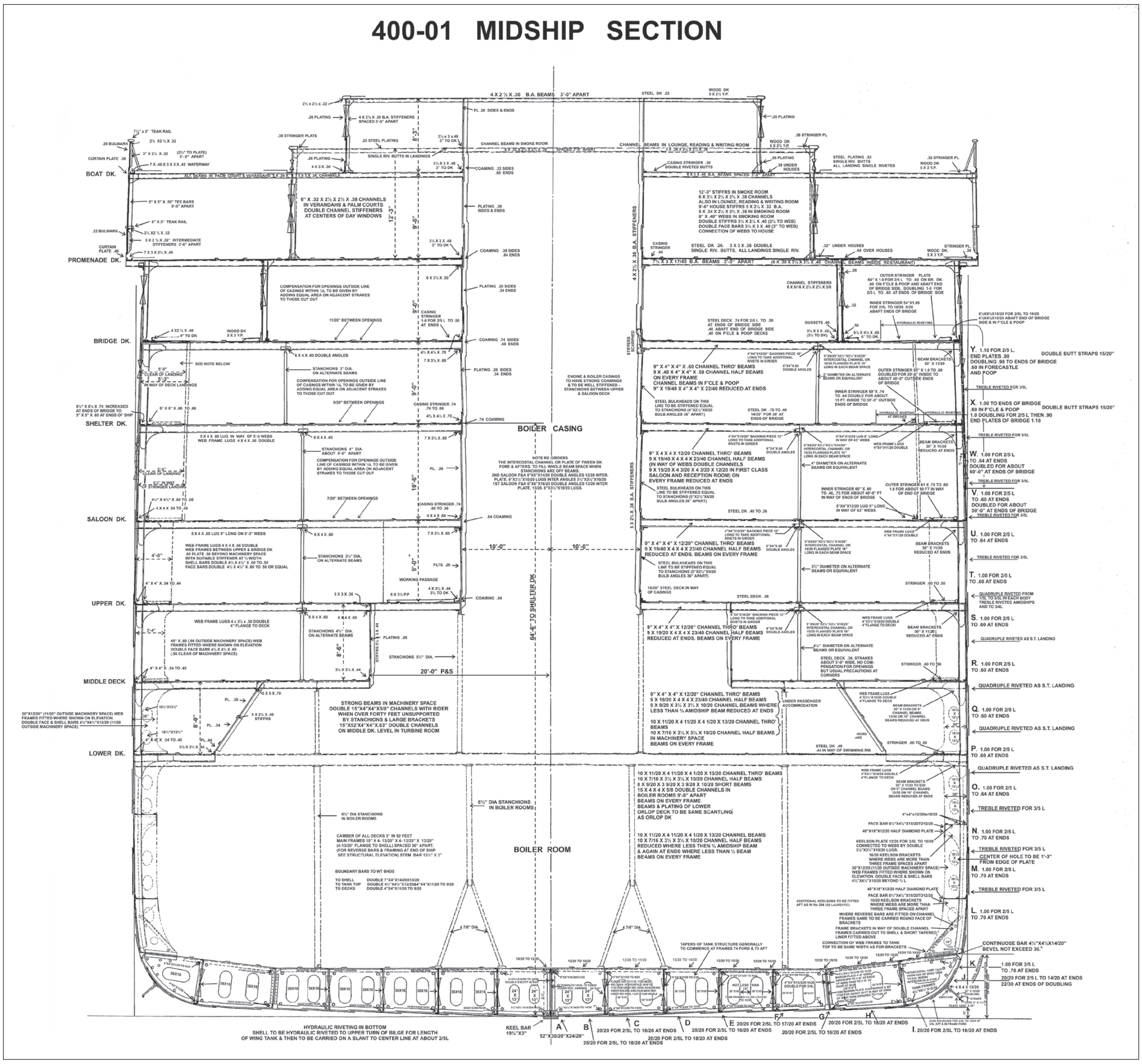

400-01 MIDSHIP SECTION
BOAT DK.
PROMENADE DK.
BRIDGE DK.
SHELTER DK.
SALOON DK.
UPPER DK.
MIDDLE DECK
LOWER DK.
BOILER CASING
BOILER ROOM
54'-6" TO SHELTER DK
10'-0"
20'-0" P&S
KEEL BAR
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
HYDRAULIC RIVETING IN BOTTOM SHELL TO BE HYDRAULIC RIVETED TO UPPER TURN OF BILGE FOR LENGTH OF WING TANK & THEN TO BE CARRIED ON A SLANT TO CENTER LINE AT ABOUT 2/5L

Fig. 4-3 **Midship Section (Full)** – The midship section of *Olympic* and *Titanic*. Unlike the original midship section provided in Chapter 1, this plan shows the fittings of the ships as completed, and is an actual midship section in that it is the view as if the ship were cut in half midway along her length. All of the major components are illustrated, including the joggled angle bars that attached the bottom shell plating to the floors, the beam heights of the decks, pillars, web frames and other structural members. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

board was laid were the 'frame furnaces'. Near these there were laid large rectangular slabs of cast iron, 5 to 6ft square and about 5in thick, which were perforated over their surfaces with round or square holes measuring about 1½in across. These iron slabs were arranged to form a perfectly horizontal surface of sufficient area to take the largest frame in the vessel under construction.

In order to get the shape of the particular frame to be bent, a mold was made by means of a long strip of iron, called a 'set iron', which usually measured about 1½in wide by ½in or ⅜in thick. After being bent to the shape of the toe of the frame on the scrive board, it was taken to the cast-iron slabs and pinned down. The angle-bar frames, which were to be fitted to the tank floors to accommodate the clinker-style bottom shell strakes, were joggled in place. The joggling was done during the process of bending the frame bars with the use of a large press.

In addition to being bent and beaten into the shape of their section of the vessel, the frame bars were

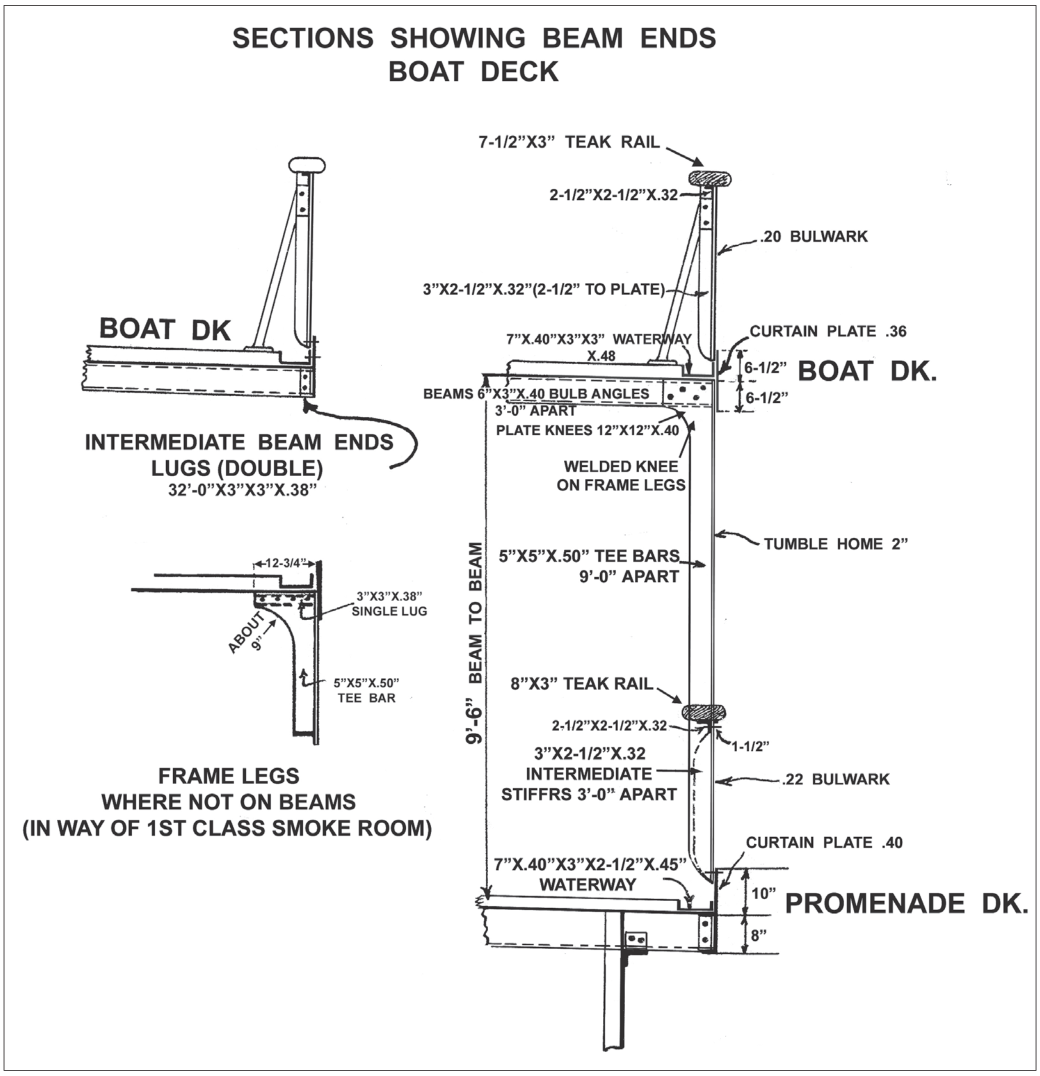

SECTIONS SHOWING BEAM ENDS
BOAT DECK
BOAT DK
INTERMEDIATE BEAM ENDS
LUGS (DOUBLE)
32'-0"X3"X3"X.38"
12-3/4"
3"X3"X.38"
SINGLE LUG
ABOUT 9"
5"X5"X.50"
TEE BAR
FRAME LEGS
WHERE NOT ON BEAMS
(IN WAY OF 1ST CLASS SMOKE ROOM)
7-1/2"X3" TEAK RAIL
2-1/2"X2-1/2"X.32
.20 BULWARK
3"X2-1/2"X.32"(2-1/2" TO PLATE)
7"X.40"X3"X3" WATERWAY
X.48
CURTAIN PLATE .36
6-1/2"
BOAT DK.
6-1/2"
BEAMS 6"X3"X.40 BULB ANGLES
3'-0" APART
PLATE KNEES 12"X12"X.40
WELDED KNEE
ON FRAME LEGS
TUMBLE HOME 2"
9'-6" BEAM TO BEAM
5"X5"X.50" TEE BARS
9'-0" APART
8"X3" TEAK RAIL
2-1/2"X2-1/2"X.32
1-1/2"
3"X2-1/2"X.32
INTERMEDIATE
STIFFRS 3'-0" APART
.22 BULWARK
CURTAIN PLATE .40
7"X.40"X3"X2-1/2"X.45"
WATERWAY
10"
PROMENADE DK.
8"

Fig. 4-4 **Beam End Connections Beneath the Boat Deck** – These sections show the connection to the frame legs supporting the outboard ends of the deck beams, and the connection of the frame legs to the curtain plate.

beveled. The frame angle had a long and short flange. The long flange pointed towards the interior of the vessel, perpendicular to the fore-and-aft middle line; the short flange was always placed against the shell. Towards the ends of the vessel, however, where the hull tapered into the stem and stern, the angle produced by the flanges of the frames changed. If the shell flanges of all the frames pointed in the same direction, the angles produced would become very obtuse at one end of the vessel and very acute at the other. With an acute angle (also called a 'closed bevel'), it was usually very difficult and sometimes impossible to achieve good riveting as the head of the rivet could not be laid up properly. In order to get open-frame bevels at the ends of the vessel, it was necessary to reverse the frames at one end, so that the shell flanges of the frame bars would point towards amidships from both ends of the vessel.

Beveling of frame bars could be done by hand or machine. The amount of bevel was determined by the loftsman from a bevel board. In machine beveling, the bar was beveled from the heel. The frame was drawn out of the furnace after it had reached full heat. One end was pinned to the end of the set iron and the other was worked round to its shape, pinned down, and kept in position on the blocks by the use of iron dogs and pins. An important concern in bending angle bars was that during cooling more contraction took place at the heel of the bar, where the material was thickest, than anywhere else. This resulted in a bar which was bent from the heel (as was the frame bar) somewhat straightening itself as it cooled, thereby reducing the curvature. The frame benders, guided solely by experience, gave more curvature to the frame than the scrive board indicated when the bar was heated so that it would achieve the desired shape as it contracted during cooling. Usually, only a few blows from a hammer were needed after the bar had cooled to bring it to the correct final curvature. When completed, each frame bar was carefully checked on the scrive board before any riveting

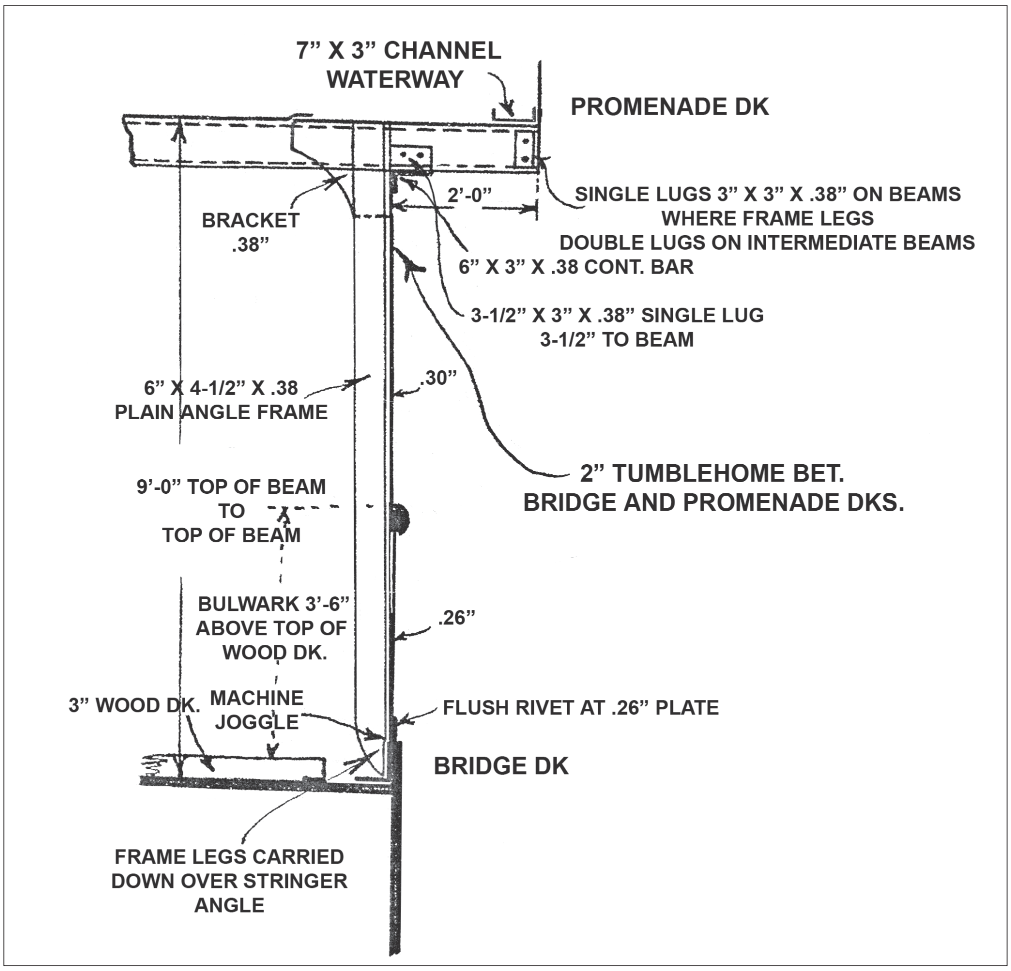

7" X 3" CHANNEL
WATERWAY
PROMENADE DK
SINGLE LUGS 3" X 3" X .38" ON BEAMS WHERE FRAME LEGS
DOUBLE LUGS ON INTERMEDIATE BEAMS
2'-0"
BRACKET .38"
6" X 3" X .38 CONT. BAR
3-1/2" X 3" X .38" SINGLE LUG 3-1/2" TO BEAM
6" X 4-1/2" X .38 PLAIN ANGLE FRAME
.30"
2" TUMBLEHOME BET. BRIDGE AND PROMENADE DKS.
9'-0" TOP OF BEAM TO TOP OF BEAM
BULWARK 3'-6" ABOVE TOP OF WOOD DK.
.26"
3" WOOD DK.
MACHINE JOGGLE
FLUSH RIVET AT .26" PLATE
BRIDGE DK
FRAME LEGS CARRIED DOWN OVER STRINGER ANGLE

Fig. 4-5 **Beam End Connections Beneath A Deck** – This section shows the connection to the frame legs supporting the outboard ends of the deck beams, and the connection of the frame legs to the stringer angle and upper sheer strake.

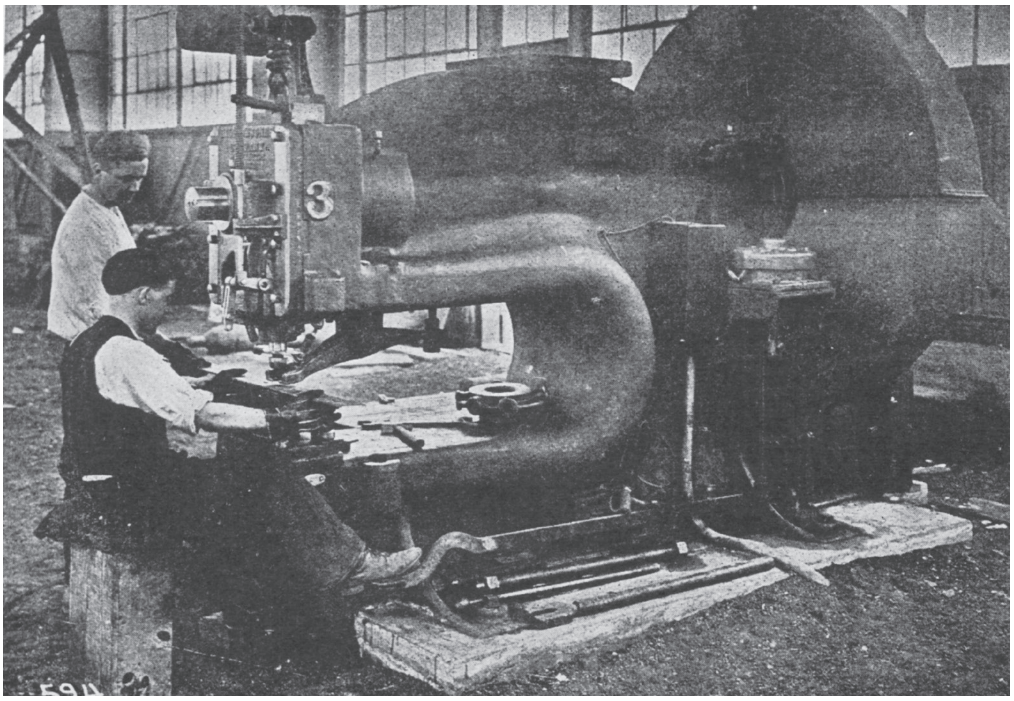


Fig 4-2a **Bar-Punching Machine** – A typical bar-punching machine in a shipyard.

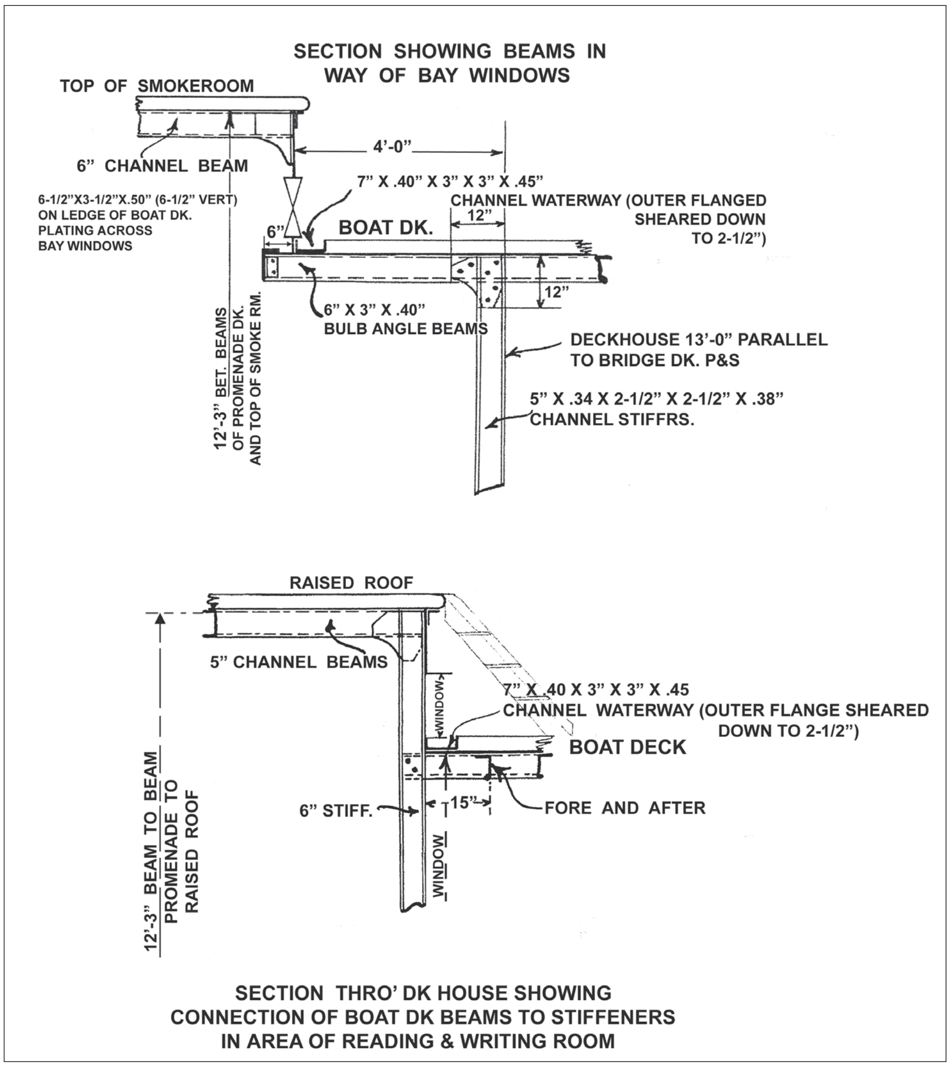

SECTION SHOWING BEAMS IN WAY OF BAY WINDOWS
TOP OF SMOKEROOM
6" CHANNEL BEAM
4'-0"
7" X .40" X 3" X 3" X .45"
CHANNEL WATERWAY (OUTER FLANGED SHEARED DOWN TO 2-1/2")
6-1/2"X3-1/2"X.50" (6-1/2" VERT) ON LEDGE OF BOAT DK. PLATING ACROSS BAY WINDOWS
6"
12"
BOAT DK.
12"
6" X 3" X .40" BULB ANGLE BEAMS
12'-3" BET. BEAMS OF PROMENADE DK. AND TOP OF SMOKE RM.
DECKHOUSE 13'-0" PARALLEL TO BRIDGE DK. P&S
5" X .34 X 2-1/2" X 2-1/2" X .38" CHANNEL STIFFRS.
RAISED ROOF
5" CHANNEL BEAMS
WINDOW
7" X .40 X 3" X 3" X .45
CHANNEL WATERWAY (OUTER FLANGE SHEARED DOWN TO 2-1/2")
BOAT DECK
12'-3" BEAM TO BEAM PROMENADE TO RAISED ROOF
6" STIFF.
15"
FORE AND AFTER
WINDOW
SECTION THRO' DK HOUSE SHOWING CONNECTION OF BOAT DK BEAMS TO STIFFENERS IN AREA OF READING & WRITING ROOM

Fig. 4-6 **Sections Through the Raised Roofs Over the A Deck Public Rooms.**

was done. The corresponding frame bar for the opposite side of the vessel was made at the same time and the two were positioned one upon the other to verify correct curvature.

Because external water pressure on the hull of a vessel is greatest where the immersed girth is greatest and as the greater weight is likely to be carried where the hold capacity is greatest, more strength is required in the transverse framing in the full middle body of a vessel than towards the ends where it gradually fines down towards the ends of the hull. To provide this additional strength, it was common to increase the thickness of the frames by $^1/_{20}$in over three-fifths of the midship length. Correspondingly, the thickness of the midship floors was also increased.

The pitch of rivet holes in the flange connected to the frame angle was similar to the pitch in the frame from which they were transferred. The rivet holes in the other flange taking the ceiling and sparring were spaced to suit the width and arrangement of the battens.

Frames in way of the double bottom

Depending on the location along the ship's length, the frame bars were cut either at the tank margin plate or at just several inches above the inner bottom plating in way of the wing tanks; in both cases, continuous angle bars were fitted, making the connection between the margin plate or inner bottom above the wing tanks and the outer shell plating watertight. The continuity of the transverse frame strength was maintained by connecting the frame legs to the tank side by large bracket plates. In the open bilge wings ahead and abaft of the wing tanks, where these brackets extended around the turn of the bilge and were attached to the margin plate, they were called 'wing brackets' or 'bilge brackets'. Amidships, where the inner bottom extended to the sides of the ship above the wing tanks, these brackets were attached through double angle lugs to the Tank Top, and so were called 'tank brackets'.

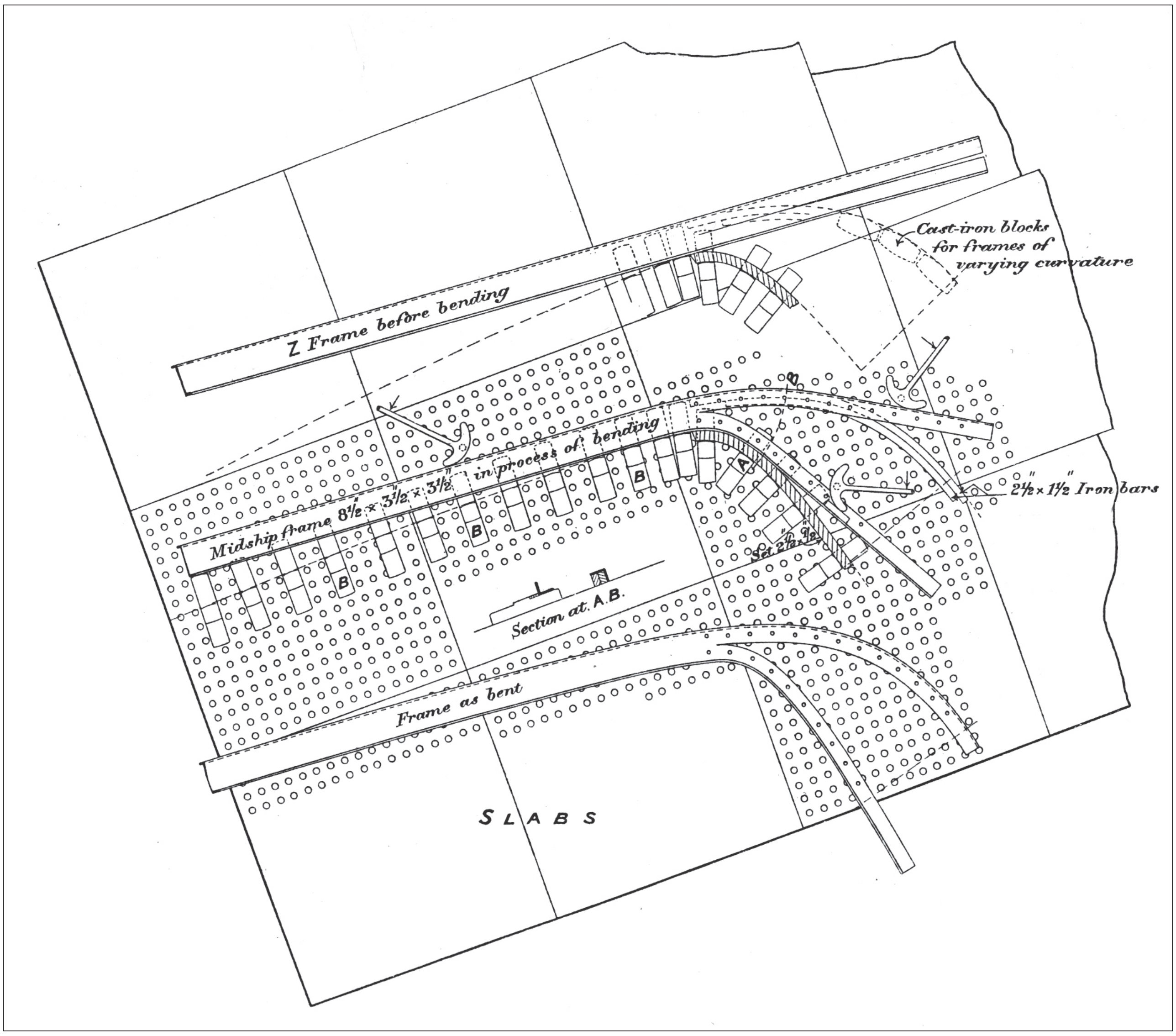

Cast-iron blocks for frames of varying curvature
Z Frame before bending
B
Midship frame 8½" × 3½" × 3½" in process of bending
B
B
B
A
2½" × 1½" Iron bars
Set 2½" × ½"
Section at A.B.
Frame as bent
SLABS

Fig. 4-7 **Bending Slab** – The layout of a bending slab. This illustration shows a bending slab being used to produce a frame from a length of Z-bar.

By connecting the floors to the vertical keel by means of angles, the continuity of the floor plate was necessarily interrupted, but the continuity of the transverse strength was maintained. The floors at the middle line were much deeper than their outboard counterparts, thus permitting a good connection and somewhat compensating for the break in the continuity of the frames and reverses. In order to ensure the watertightness of the tank, a continuous bar was fitted to the lower extremity of the margin plate to connect it to the outer bottom. This necessitated another break in the continuity of the frame bars. The depth of the floor plate, however, enabled a satisfactory connection to be made between the transverse framing inside and outside of the tank by means of the bracket plates already mentioned. The reverse bars were also intercostal between the vertical keel and the margin plate. Commencing outside the margin plate, in the open bilge wings ahead and abaft of the wing tanks the reverse frames were continued along the upper edge of the bilge brackets and up the frame bars to its prescribed height. Amidships, the reverse frames of the tank floors were continued intercostally along the wing tank floors; above the Tank Top, the upper edges of the tank brackets were stiffened by an angle fitted along the same side as the reverses on the transverse frames.

As stated previously, the bottom frames corresponding with the outer shell plating were joggled in clinker fashion. This was done to eliminate the use of the tapered packing pieces ordinarily associated with this type of plating.

Deep framing

In the earliest method of framing of iron and steel ships, ordinary frames and reverse frames were fitted throughout the length of the vessel. When the depth of a hold was beyond a certain specified dimension

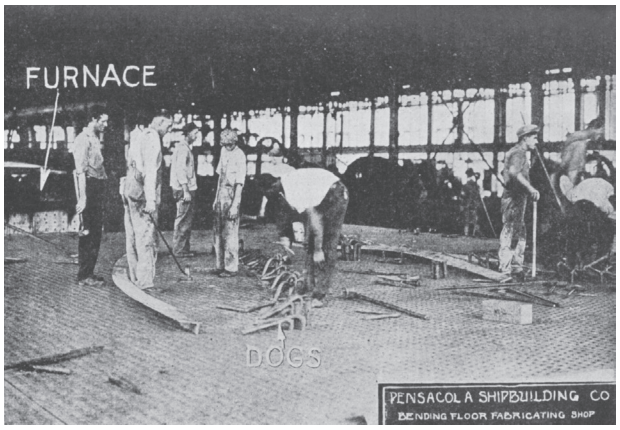


Fig. 4-8 **The Bending Floor** – A bending floor as seen in a period shipyard. This would have been similar to that used at Harland & Wolff.

in relation to the vessel's other principal dimensions, one or more tiers of hold beams were employed to tie the transverse frames together across the breadth of the hull. This was required to maintain the rigidity of the ship's sides against the force of the water pressing inward against the shell. Hold beams were very similar to deck beams, both in appearance and in their manner of attachment to the frames, except they were not plated over with deck plating, leaving the hold space open throughout its height to the underside of the deck forming the top of the hold. Additionally, unlike deck beams, hold beams were not located on every frame; instead, they were located on intervals of every third to as much as every tenth frame.

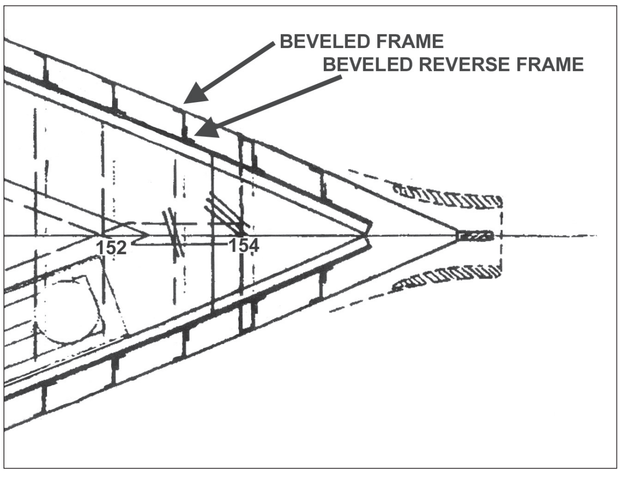


Fig. 4-9 **Example of Framing at the Ends of the Ship** – A detail showing the deck plates and frames at the very forward end of *Titanic*'s Shelter Deck (C), including the stem casting. As the hull narrowed at the bow and stern, the channel-section frames employed throughout the midbody were replaced with frames of built-up construction. These consisted of two angle bar members – the outer frame which attached to the shell, and the inner reverse frame. Both of these frames were beveled to match the increasing fineness of the hull fore and aft. *(Illustration by Bruce Beveridge based on original H&W Shelter Deck Iron plan)*

The introduction of one or more tiers of beams running across the hold proved to be a great source of inconvenience in the stowage of certain kinds of cargo due to the interruptions caused throughout the height of the hold along its length. In searching to remedy this deficiency, shipbuilders found that tiers of hold beams could be dispensed with by modifying the transverse framing to provide sufficient resistance to the forces acting upon the ship's sides. Initially, the answer to the problem was found in the introduction of 'deep frames' in lieu of all the ordinary frames and reverse frames throughout the hold space.

A 'deep frame' was the result of increasing the depth of the ordinary frames by approximately 50 per cent; the overall increase in depth was generally achieved by fabricating built frames utilizing two heavy angle bars having an increased depth, while decreasing the amount of overlap between the two angles. While deep frames took the place of the ordinary frame and reverse frame, their chief function was to compensate for the tiers of hold beams which were dispensed with.

Instead of fitting together the two angles in the same fashion as was usual for the ordinary frame and reverse (the toe of the frame being flush with the heel of the reverse frame), the connection was made solely by means of a 3 to 3½in lap, in which case it was found preferable to fit angles. The lug piece which was usually fitted in order to get a good connection between the stringers and the reverse transverse frames was placed on the back frame of the reversed frame. This was better than fitting the frame and reverse, where not only was a piece of packing iron required, but satisfactory riveting was difficult to obtain. Like channel frames, deep framing was only adopted for the frame legs in vessels with double bottoms. The bending and beveling was done as described for ordinary frames.

Like the hold beams that deep frames replaced, the benefits they provided came at a price, the penalty in this instance being increased weight. The eventual solution to the problem was found in the adoption of another form of built frame, the 'web frame'.

Web frames

Web frames are massive, deep, built-up members fitted into the hull to add strength and rigidity at points of special stress and to support the side stringers, which, in turn, support the transverse frames. Web frames made a belt of great rigidity around the ship in line with their position. The depth, spacing and number of the web frames was governed by the depth of the vessel, while the thickness of the plates was similar to that

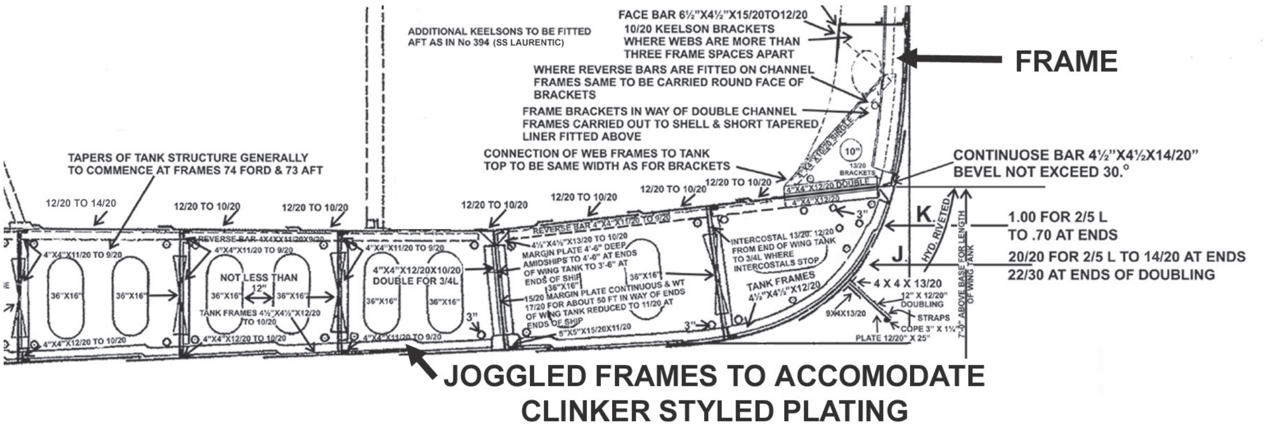

ADDITIONAL KEELSONS TO BE FITTED AFT AS IN No 394 (SS LAURENTIC)
FACE BAR 6½"X4½"X15/20TO12/20
10/20 KEELSON BRACKETS WHERE WEBS ARE MORE THAN THREE FRAME SPACES APART
FRAME
WHERE REVERSE BARS ARE FITTED ON CHANNEL FRAMES SAME TO BE CARRIED ROUND FACE OF BRACKETS
FRAME BRACKETS IN WAY OF DOUBLE CHANNEL FRAMES CARRIED OUT TO SHELL & SHORT TAPERED LINER FITTED ABOVE
CONNECTION OF WEB FRAMES TO TANK TOP TO BE SAME WIDTH AS FOR BRACKETS
TAPERS OF TANK STRUCTURE GENERALLY TO COMMENCE AT FRAMES 74 FORD & 73 AFT
CONTINUOSE BAR 4½"X4½X14/20" BEVEL NOT EXCEED 30.°
12/20 TO 14/20
12/20 TO 10/20
12/20 TO 10/20
12/20 TO 10/20
12/20 TO 10/20
12/20 TO 10/20
12/20 TO 10/20
REVERSE BAR 4X4XX11/20X9/20
REVERSE BAR 4"X4"X11/20 TO 9/20
4"X4"X11/20 TO 9/20
4"X4"X11/20 TO 9/20
4"X4"X11/20 TO 9/20
36"X16"
NOT LESS THAN 12"
4"X4"X12/20X10/20 DOUBLE FOR 3/4L
TANK FRAMES 4½"X4½"X12/20 TO 10/20
4"X4"X12/20 TO 10/20
4"X4"X12/20 TO 10/20
4"X4"X11/20 TO 9/20
3"
4½"X4½"X13/20 TO 10/20
MARGIN PLATE 4'-6" DEEP AMIDSHIPS TO 4'-0" AT ENDS OF WING TANK TO 3'-6" AT ENDS OF SHIP
15/20 MARGIN PLATE CONTINUOUS & WT 17/20 FOR ABOUT 50 FT IN WAY OF ENDS OF WING TANK REDUCED TO 11/20 AT ENDS OF SHIP
5"X5"X15/20X11/20
INTERCOSTAL 13/20. 12/20 FROM END OF WING TANK TO 3/4L WHERE INTERCOSTALS STOP
TANK FRAMES 4½"X4½"X12/20
1"X4"X10/20 SINGLE
10"
13/20 BRACKETS
4"X4"X12/20 DOUBLE
4"X4"X12/20
K.
J.
HYD. RIVETED
1.00 FOR 2/5 L TO .70 AT ENDS
20/20 FOR 2/5 L TO 14/20 AT ENDS
22/30 AT ENDS OF DOUBLING
4 X 4 X 13/20
12" X 12/20" DOUBLING
9X4X13/20
STRAPS
COPE 3" X 1½"
PLATE 12/20" X 25"
7'-0" ABOVE BASE FOR LENGTH OF WING TANK
JOGGLED FRAMES TO ACCOMODATE CLINKER STYLED PLATING

Fig. 4-10 **Connection of Frame at Tank Margin Plate.** *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

of the ordinary frames. While some of the individual structural members employed in the fabrication of web frames were of heavier scantlings than those of the deep frames they superseded, a considerable saving in weight was achieved because, by virtue of their greater strength, web frames were not required on every frame. Instead, depending upon location, intervals of anywhere from every other frame as great as every sixth frame were found to be satisfactory, with ordinary solid or built frames being used on the remaining frame locations.

The main member of each web frame was a deep web of plate which was lightened by cutting holes along the neutral axis. *Titanic*'s web frames were generally 30in deep. Two vertical-angle 'shell bars' attached the plate to the shell plating, and two angle 'face bars' formed the inboard flange of the frame. *Titanic*'s web frames were placed on approximately every third frame throughout the boiler rooms and Turbine Engine Room, and on approximately every second frame in the Reciprocating Engine Room, and extended unbroken from the tank sides to the Lower Deck (G) above. From here they were continued intercostally between the stringers of the Lower Deck (G) and Middle Deck (F). Some of these web frames were carried intercostally as high as the Bridge Deck (B). Web frames were fitted to the hull ahead and abaft the boiler and machinery spaces as well, but at an interval of four frames apart, eventually increasing to six frames apart towards the ends, and then to nine frames apart at the very forward end.

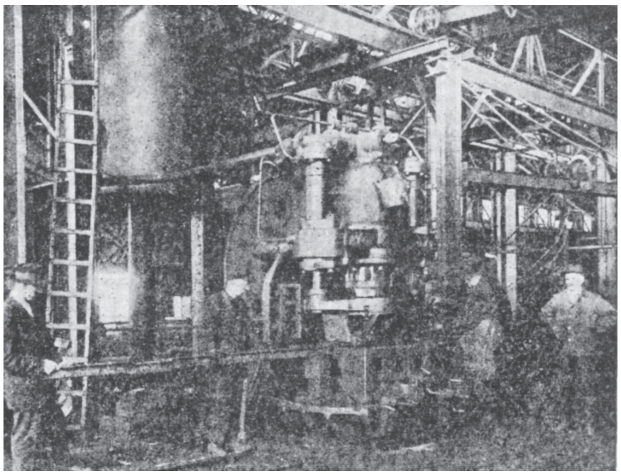


Fig. 4-11 **Joggler** – A common shipyard joggling press in which channel and angle bars were shaped.

In conjunction with the web frames two web stringers, or 'keelsons', were fitted intercostally between the web frames and over the transverse frames between the Tank Top and the Lower Deck (G) so that the stiffness furnished by the web frames could be utilized by the shell plating.

The connection of the stringers to the web frames was made by double angle lugs, and also by angle face bars and half diamond plates. Angle bar lugs were also used to connect the web stringers to the inside of the shell plates and frame bars. The connection of the web frames to the tank side was made by double angles. In order to make the transverse strength afforded by web frames as continuous as possible all around the transverse circumference of the hull, extra strong through-beams with deep knees were fitted to the head of the web frames where practicable.

Beams

A beam is a steel bar uniting the ship's frames and preventing, by its own tensile strength and rigidity,

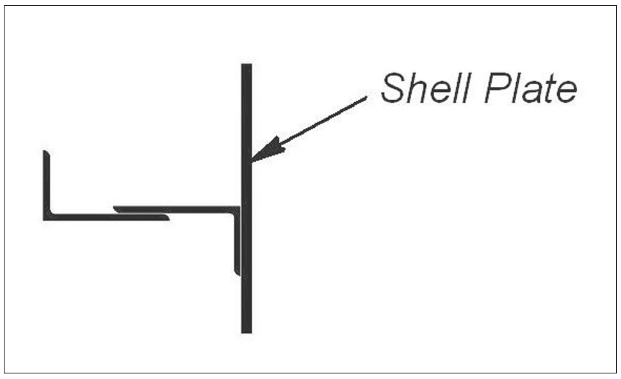

Shell Plate

Fig. 4-12 **Deep Frame** – A typical transverse deep frame. The use of this type of built frame as a transverse hull frame was made all but obsolete by the introduction of web frames. *(Scott Andrews collection)*

the tendency of the frame heads to move away from each other or to move toward each other when a vessel is subject to stresses during loading or from the pressure of the water acting upon the immersed skin of the ship. Beams thus perform the function of both struts and ties.

As a general rule, it is preferable to fit beams to every frame. Where a system of widely spaced frames was adopted, as in the design of the *Olympic*-class ships, the beams under the steel decks were located upon every frame out of necessity.

Like the frames, the transverse beams of *Titanic*, up to and including the Bridge Deck (B), were of channel section, with the largest of these being 92ft long and weighing 1¼ tons. Most of these beams were 9in deep; however, the depth of the beams beneath the decks outside of the passenger accommodation areas on the Middle Deck (F) and Lower Deck (G), as well as those beneath the Orlop and Lower Orlop Decks, were increased to 10in. The beams beneath the decks above the Bridge Deck (B) were generally of bulb angle.

As with the frames, the beams were manufactured as straight bars cut to rough oversized length. However, all of *Titanic*'s beams had a 'camber' (slight upward rounding) of 3in in 92ft, achieved by cold bending in a 'squeezing machine'. The length of every beam in the ship's deck was obtained from the mold upon which they were indicated. After the beams were cambered and cut to their respective lengths, the next step was to prepare the beam knees. The ends of each beam were connected to the respective frame through beam knees having a depth of 30in throughout, a considerable increase above the Board of Trade-required minimum of two-and-a-half times the depth of the beam. The knees were simply brackets formed of plates from $^{9}/_{20}$ to $^{13}/_{20}$in-thick steel riveted to the back of the vertical

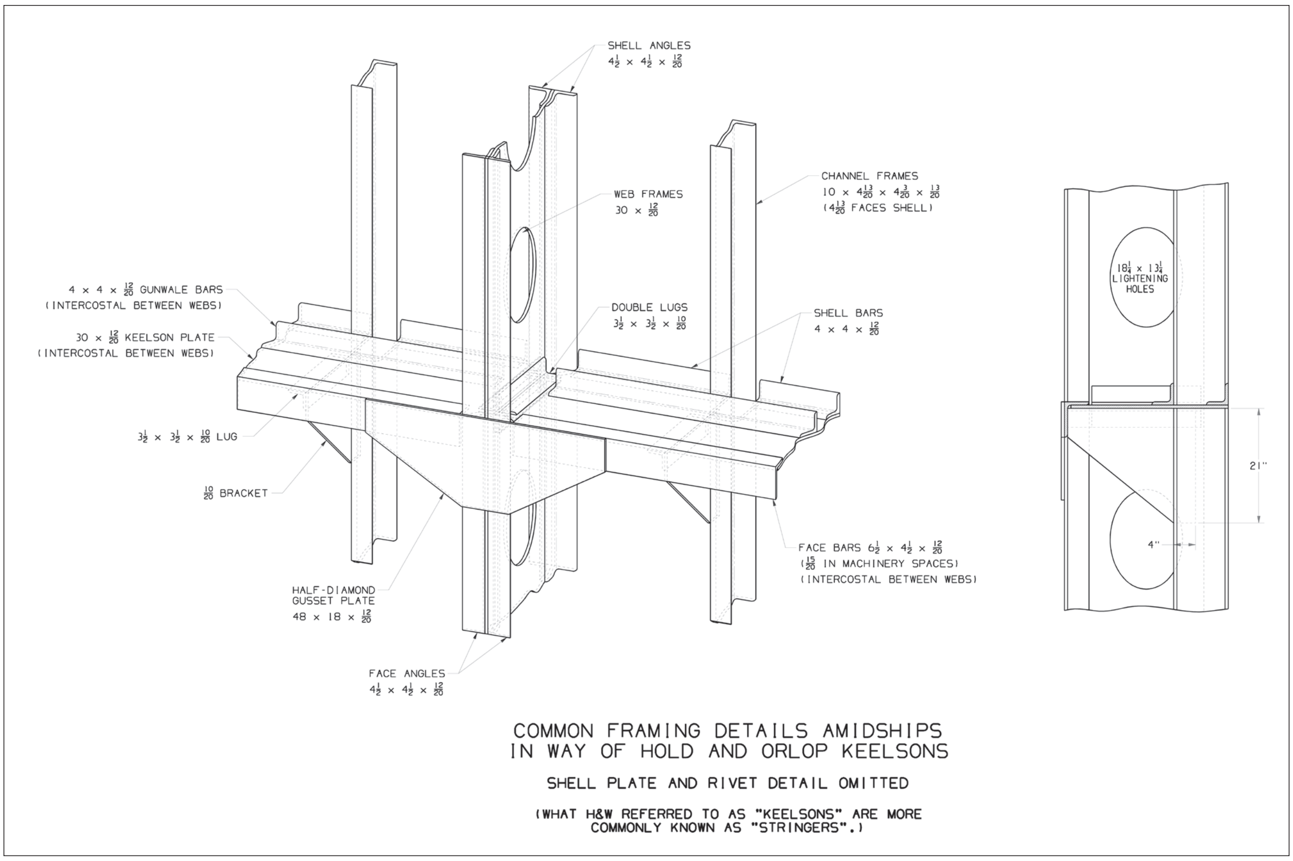

SHELL ANGLES
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{12}{20}$
CHANNEL FRAMES
$10 \times 4\frac{13}{20} \times 4\frac{3}{20} \times \frac{13}{20}$
($4\frac{13}{20}$ FACES SHELL)
WEB FRAMES
$30 \times \frac{12}{20}$
$4 \times 4 \times \frac{12}{20}$ GUNWALE BARS
(INTERCOSTAL BETWEEN WEBS)
$30 \times \frac{12}{20}$ KEELSON PLATE
(INTERCOSTAL BETWEEN WEBS)
DOUBLE LUGS
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{10}{20}$
SHELL BARS
$4 \times 4 \times \frac{12}{20}$
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{10}{20}$ LUG
$\frac{10}{20}$ BRACKET
FACE BARS $6\frac{1}{2} \times 4\frac{1}{2} \times \frac{12}{20}$
($\frac{15}{20}$ IN MACHINERY SPACES)
(INTERCOSTAL BETWEEN WEBS)
HALF-DIAMOND
GUSSET PLATE
$48 \times 18 \times \frac{12}{20}$
FACE ANGLES
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{12}{20}$
$18\frac{1}{4} \times 13\frac{1}{4}$
LIGHTENING
HOLES
21"
4"
COMMON FRAMING DETAILS AMIDSHIPS
IN WAY OF HOLD AND ORLOP KEELSONS
SHELL PLATE AND RIVET DETAIL OMITTED
(WHAT H&W REFERRED TO AS "KEELSONS" ARE MORE
COMMONLY KNOWN AS "STRINGERS".)

Fig. 4-13 **Side Keelsons –** Detail of side keelsons and connections to framing within machinery and boiler spaces. *(Illustration by Scott Andrews)*

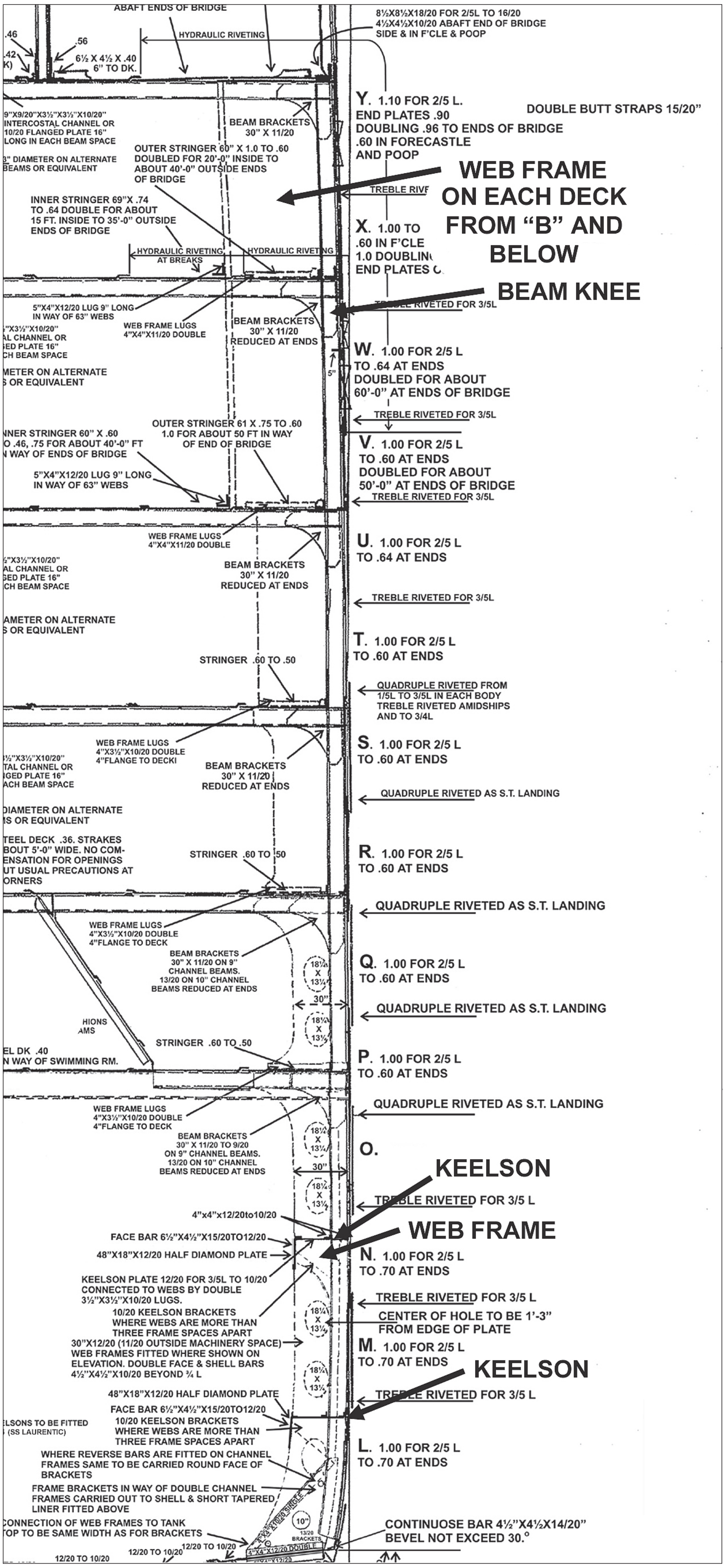

ABAFT ENDS OF BRIDGE
8½X8½X18/20 FOR 2/5L TO 16/20
4½X4½X10/20 ABAFT END OF BRIDGE
SIDE & IN F'CLE & POOP
.46
.56
.42
HYDRAULIC RIVETING
6½ X 4½ X .40
6" TO DK.
Y. 1.10 FOR 2/5 L.
END PLATES .90
DOUBLING .96 TO ENDS OF BRIDGE
.60 IN FORECASTLE
AND POOP
DOUBLE BUTT STRAPS 15/20"
9"X9/20"X3½"X3½"X10/20"
INTERCOSTAL CHANNEL OR
10/20 FLANGED PLATE 16"
LONG IN EACH BEAM SPACE
3" DIAMETER ON ALTERNATE
BEAMS OR EQUIVALENT
BEAM BRACKETS
30" X 11/20
OUTER STRINGER 60" X 1.0 TO .60
DOUBLED FOR 20'-0" INSIDE TO
ABOUT 40'-0" OUTSIDE ENDS
OF BRIDGE
WEB FRAME
ON EACH DECK
FROM "B" AND
BELOW
TREBLE RIVETED
INNER STRINGER 69"X .74
TO .64 DOUBLE FOR ABOUT
15 FT. INSIDE TO 35'-0" OUTSIDE
ENDS OF BRIDGE
X. 1.00 TO
.60 IN F'CLE
1.0 DOUBLING
END PLATES
HYDRAULIC RIVETING
AT BREAKS
HYDRAULIC RIVETING
BEAM KNEE
TREBLE RIVETED FOR 3/5L
5"X4"X12/20 LUG 9" LONG
IN WAY OF 63" WEBS
"X3½"X10/20"
AL CHANNEL OR
ED PLATE 16"
CH BEAM SPACE
WEB FRAME LUGS
4"X4"X11/20 DOUBLE
BEAM BRACKETS
30" X 11/20
REDUCED AT ENDS
METER ON ALTERNATE
S OR EQUIVALENT
W. 1.00 FOR 2/5 L
TO .64 AT ENDS
DOUBLED FOR ABOUT
60'-0" AT ENDS OF BRIDGE
5"
TREBLE RIVETED FOR 3/5L
OUTER STRINGER 61 X .75 TO .60
1.0 FOR ABOUT 50 FT IN WAY
OF END OF BRIDGE
NNER STRINGER 60" X .60
O .46, .75 FOR ABOUT 40'-0" FT
N WAY OF ENDS OF BRIDGE
V. 1.00 FOR 2/5 L
TO .60 AT ENDS
DOUBLED FOR ABOUT
50'-0" AT ENDS OF BRIDGE
5"X4"X12/20 LUG 9" LONG
IN WAY OF 63" WEBS
TREBLE RIVETED FOR 3/5L
WEB FRAME LUGS
4"X4"X11/20 DOUBLE
U. 1.00 FOR 2/5 L
TO .64 AT ENDS
"X3½"X10/20"
AL CHANNEL OR
ED PLATE 16"
CH BEAM SPACE
BEAM BRACKETS
30" X 11/20
REDUCED AT ENDS
TREBLE RIVETED FOR 3/5L
AMETER ON ALTERNATE
S OR EQUIVALENT
T. 1.00 FOR 2/5 L
TO .60 AT ENDS
STRINGER .60 TO .50
QUADRUPLE RIVETED FROM
1/5L TO 3/5L IN EACH BODY
TREBLE RIVETED AMIDSHIPS
AND TO 3/4L
WEB FRAME LUGS
4"X3½"X10/20 DOUBLE
4"FLANGE TO DECK
½"X3½"X10/20"
TAL CHANNEL OR
GED PLATE 16"
ACH BEAM SPACE
BEAM BRACKETS
30" X 11/20
REDUCED AT ENDS
S. 1.00 FOR 2/5 L
TO .60 AT ENDS
QUADRUPLE RIVETED AS S.T. LANDING
DIAMETER ON ALTERNATE
S OR EQUIVALENT
TEEL DECK .36. STRAKES
BOUT 5'-0" WIDE. NO COM-
ENSATION FOR OPENINGS
UT USUAL PRECAUTIONS AT
ORNERS
STRINGER .60 TO .50
R. 1.00 FOR 2/5 L
TO .60 AT ENDS
QUADRUPLE RIVETED AS S.T. LANDING
WEB FRAME LUGS
4"X3½"X10/20 DOUBLE
4"FLANGE TO DECK
BEAM BRACKETS
30" X 11/20 ON 9"
CHANNEL BEAMS.
13/20 ON 10" CHANNEL
BEAMS REDUCED AT ENDS
18¼ X 13¼
Q. 1.00 FOR 2/5 L
TO .60 AT ENDS
30"
QUADRUPLE RIVETED AS S.T. LANDING
HIONS
AMS
18¼ X 13¼
STRINGER .60 TO .50
EL DK .40
N WAY OF SWIMMING RM.
P. 1.00 FOR 2/5 L
TO .60 AT ENDS
QUADRUPLE RIVETED AS S.T. LANDING
WEB FRAME LUGS
4"X3½"X10/20 DOUBLE
4"FLANGE TO DECK
BEAM BRACKETS
30" X 11/20 TO 9/20
ON 9" CHANNEL BEAMS.
13/20 ON 10" CHANNEL
BEAMS REDUCED AT ENDS
18¼ X 13¼
O.
30"
KEELSON
18¼ X 13¼
TREBLE RIVETED FOR 3/5 L
4"x4"x12/20to10/20
WEB FRAME
FACE BAR 6½"X4½"X15/20TO12/20
48"X18"X12/20 HALF DIAMOND PLATE
N. 1.00 FOR 2/5 L
TO .70 AT ENDS
KEELSON PLATE 12/20 FOR 3/5L TO 10/20
CONNECTED TO WEBS BY DOUBLE
3½"X3½"X10/20 LUGS.
10/20 KEELSON BRACKETS
WHERE WEBS ARE MORE THAN
THREE FRAME SPACES APART
TREBLE RIVETED FOR 3/5 L
CENTER OF HOLE TO BE 1'-3"
FROM EDGE OF PLATE
18¼ X 13¼
30"X12/20 (11/20 OUTSIDE MACHINERY SPACE)
WEB FRAMES FITTED WHERE SHOWN ON
ELEVATION. DOUBLE FACE & SHELL BARS
4½"X4½"X10/20 BEYOND ¾ L
M. 1.00 FOR 2/5 L
TO .70 AT ENDS
18¼ X 13¼
KEELSON
48"X18"X12/20 HALF DIAMOND PLATE
TREBLE RIVETED FOR 3/5 L
FACE BAR 6½"X4½"X15/20TO12/20
LSONS TO BE FITTED
(SS LAURENTIC)
10/20 KEELSON BRACKETS
WHERE WEBS ARE MORE THAN
THREE FRAME SPACES APART
L. 1.00 FOR 2/5 L
TO .70 AT ENDS
WHERE REVERSE BARS ARE FITTED ON CHANNEL
FRAMES SAME TO BE CARRIED ROUND FACE OF
BRACKETS
FRAME BRACKETS IN WAY OF DOUBLE CHANNEL
FRAMES CARRIED OUT TO SHELL & SHORT TAPERED
LINER FITTED ABOVE
CONNECTION OF WEB FRAMES TO TANK
TOP TO BE SAME WIDTH AS FOR BRACKETS
10"
13/20
BRACKETS
CONTINUOSE BAR 4½"X4½X14/20"
BEVEL NOT EXCEED 30.°
12/20 TO 10/20
12/20 TO 10/20
12/20 TO 10/20
4"X4"X12/20 DOUBLE

Fig. 4-14 **Web Frames** – Web frames of several designs were employed at regular intervals as high as B Deck. The web stringers, or 'side keelsons,' are shown here, along with the web frames and their lightening holes. Web frames were also fitted in certain highly stressed areas within the deckhouses of the superstructure. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

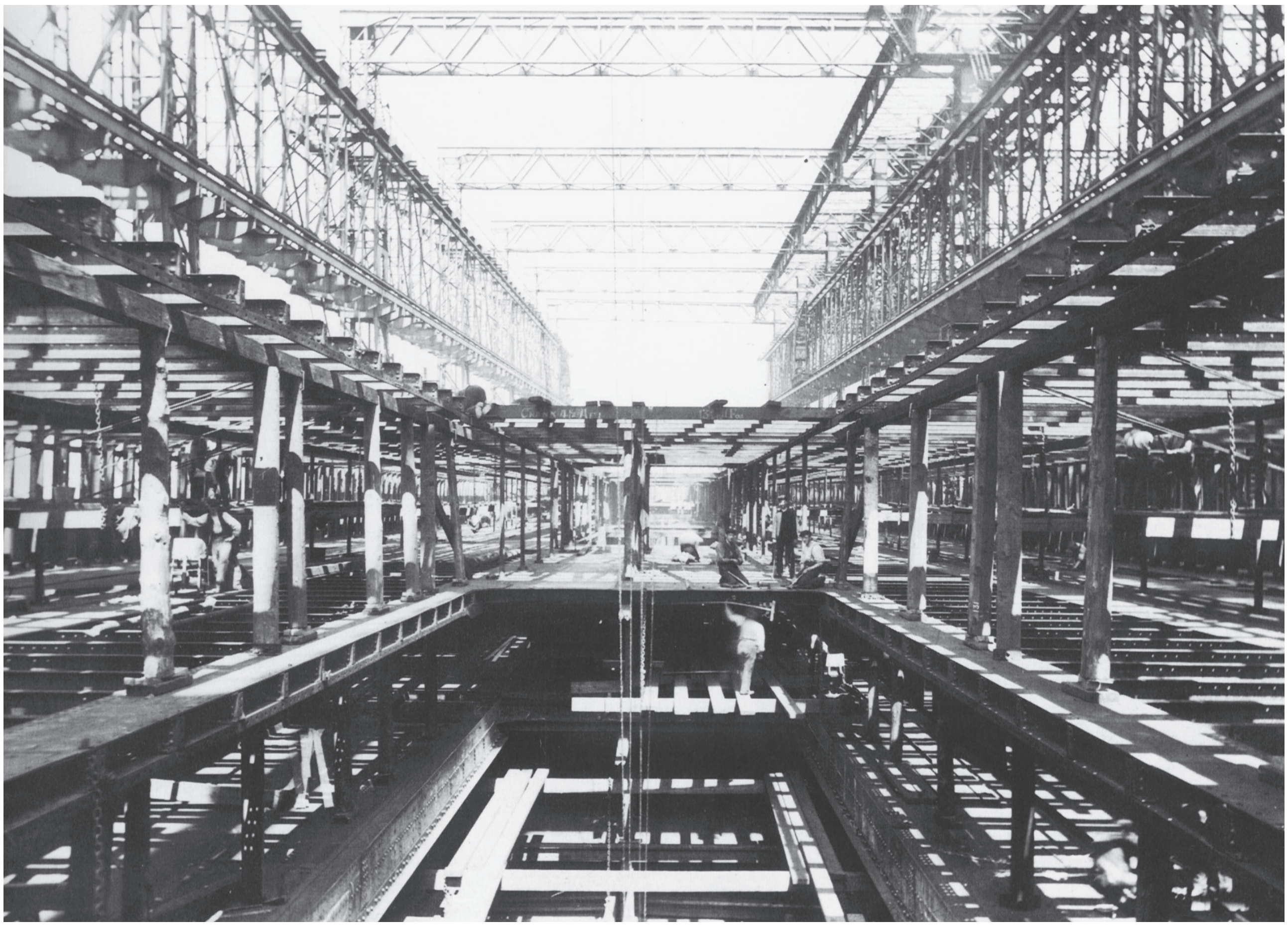


Fig. 4-15 **Internal View of Framing in Course of Construction** – *Titanic*'s Shelter Deck (C) looking aft and down into the Saloon Deck (D) and Upper Deck (E); the manner in which the deck beams are interrupted to accommodate openings through the decks – the Nos 3 and 4 boiler casing in this instance – is clearly visible, as are the rough timber shores used to support the inboard ends of these beams until the steel bulkheads and framing of the casing have been completed. The marking painted onto the web of the Bridge Deck (B) beam at the center of the image identifies this beam for the ship fitters as being 'cranked 4½in aft' which, in this instance, was done to allow clearance for the soil pipes beneath the row of water closets within the ladies' lavatory which would be situated against the after bulkhead of the boiler casing at this location. *(*The Engineer*/Authors' collection)*

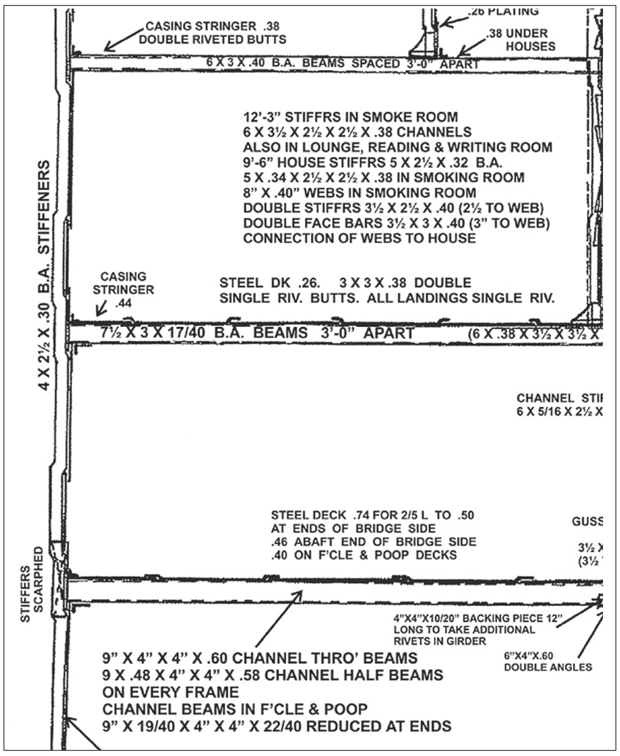

.26 PLATING
CASING STRINGER .38
DOUBLE RIVETED BUTTS
.38 UNDER
HOUSES
6 X 3 X .40 B.A. BEAMS SPACED 3'-0" APART
12'-3" STIFFRS IN SMOKE ROOM
6 X 3½ X 2½ X 2½ X .38 CHANNELS
ALSO IN LOUNGE, READING & WRITING ROOM
9'-6" HOUSE STIFFRS 5 X 2½ X .32 B.A.
5 X .34 X 2½ X 2½ X .38 IN SMOKING ROOM
8" X .40" WEBS IN SMOKING ROOM
DOUBLE STIFFRS 3½ X 2½ X .40 (2½ TO WEB)
DOUBLE FACE BARS 3½ X 3 X .40 (3" TO WEB)
CONNECTION OF WEBS TO HOUSE
4 X 2½ X .30 B.A. STIFFENERS
CASING
STRINGER
.44
STEEL DK .26. 3 X 3 X .38 DOUBLE
SINGLE RIV. BUTTS. ALL LANDINGS SINGLE RIV.
7½ X 3 X 17/40 B.A. BEAMS 3'-0" APART
(6 X .38 X 3½ X 3½ X
CHANNEL STI
6 X 5/16 X 2½ X
STEEL DECK .74 FOR 2/5 L TO .50
AT ENDS OF BRIDGE SIDE
.46 ABAFT END OF BRIDGE SIDE
.40 ON F'CLE & POOP DECKS
GUSS
3½ X
(3½
STIFFERS
SCARPHED
4"X4"X10/20" BACKING PIECE 12"
LONG TO TAKE ADDITIONAL
RIVETS IN GIRDER
9" X 4" X 4" X .60 CHANNEL THRO' BEAMS
9 X .48 X 4" X 4" X .58 CHANNEL HALF BEAMS
ON EVERY FRAME
CHANNEL BEAMS IN F'CLE & POOP
9" X 19/40 X 4" X 4" X 22/40 REDUCED AT ENDS
6"X4"X.60
DOUBLE ANGLES

Fig. 4-16 **Specification of Beams, B Deck and Above** – A section of the Midship Plan showing the general specifications for B Deck on up. B Deck had 9in channel beams, A Deck had 7½in bulb angles, and the Boat Deck had 6in bulb angles. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

flange of the beam; the outboard legs of the knees fit into the bosom of the frames. A total of 14 rivets connected the ends of each beam to the respective frame through a knee bracket, the rivets employed being of ⅜in diameter, reducing to ¾in diameter toward the ends of the vessel.

Setting the pitch of the rivet holes in the horizontal flange of the beam taking the deck plates was next. The rivets connecting a steel deck to the beams were generally on a pitch from 7 to 8 diameters apart, though in some cases the regularity of this spacing was interfered with. On the deck stringer plate and on the deck plates around all deckhouses, hatches, casings, etc., there were angle bars forming the connection between the deck stringer and the sheer strake, and between the deck plates and deckhouse

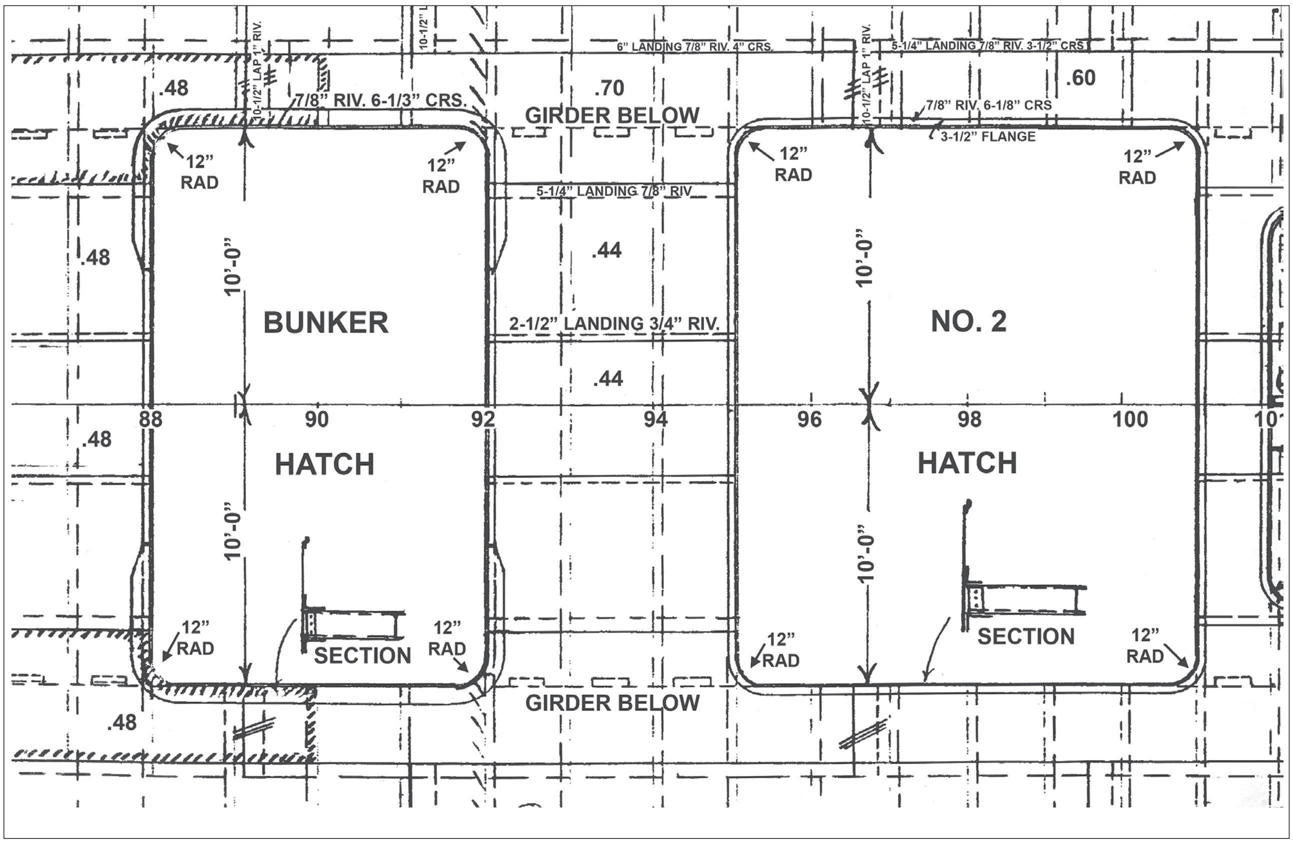

6" LANDING 7/8" RIV. 4" CRS.
5-1/4" LANDING 7/8" RIV. 3-1/2" CRS.
10-1/2" LAP 1" RIV.
.48
7/8" RIV. 6-1/3" CRS.
.70
GIRDER BELOW
.60
7/8" RIV. 6-1/8" CRS
3-1/2" FLANGE
12" RAD
5-1/4" LANDING 7/8" RIV
.44
10'-0"
BUNKER
2-1/2" LANDING 3/4" RIV.
NO. 2
88
90
92
94
96
98
100
HATCH
SECTION
GIRDER BELOW

Fig. 4-17 **C Deck Hatches** – The No.2 and No.3 Hatch openings on C Deck showing the coamings and the reinforcement of the plating around the openings. *(Illustration by Bruce Beveridge based on original H&W Shelter Deck Iron plan)*

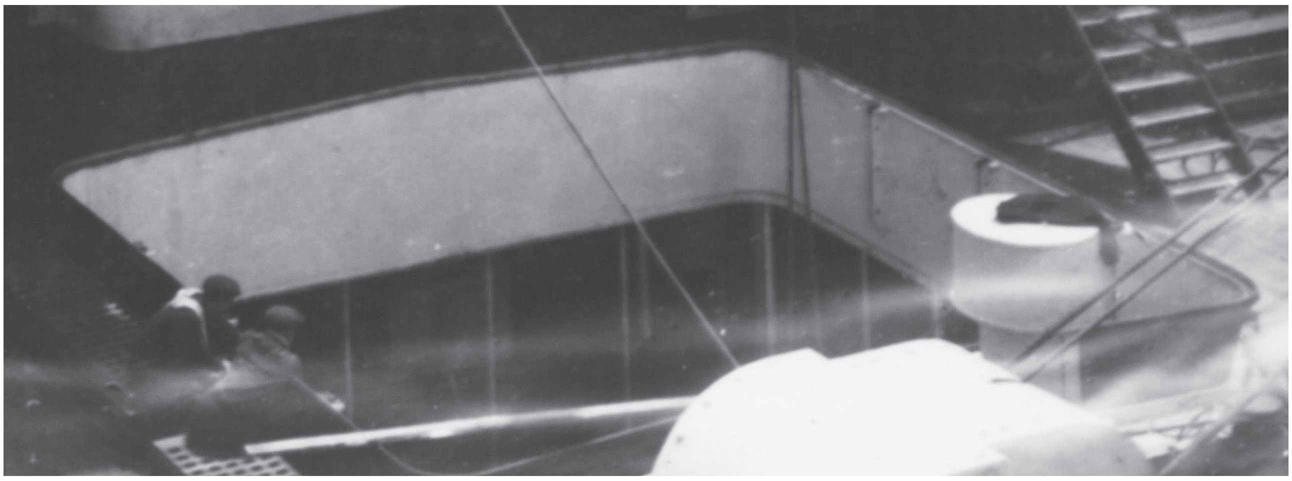


Fig. 4-18 ***Olympic*'s No.2 Hatch** – A view down into *Olympic*'s No.2 Hatch from the forward end of B Deck. The many support pillars within the Third Class open space on D Deck can be seen.

bulkheads, the hatch coamings, and the sides of the casings. The positions of all such bars, as supplied to the outside workman by the ship's draftsmen, were indicated on either a deck plan or on what was called a 'beam list'. Care had to be taken to set off all the rivet holes in the edge laps of the strakes of deck plating. After marking off the positions of these particular rivet holes, the remaining rivet holes were marked, as nearly as possible, 7 or 8 diameters apart and the holes were then punched.

In way of all hatchways and casings, the beams necessarily only extended from the frames to the hatch coaming. When hatchways are very long, and when they come in the middle length of the vessel (as in the case of the boiler casings) a serious reduction in transverse strength can result unless adequate measures are adopted to compensate for the interruption in continuity of these transverse members. It is necessary to carefully protect all deck openings, especially when situated upon the weather decks, as these are the most exposed to the destructive forces of shipped seas, etc. This protection was afforded to the hatchways on *Titanic* by fitting vertical side plates, or hatch coamings, along the sides and ends of the openings and carrying them to a minimum height of 2ft 6in above the deck on the weather decks. The hatch coamings not only afforded protection to the hatch openings, but also provided a means of binding together the beam-ends.

An extra-strong deep beam was fitted at all hatch ends, and consisted of a bulb plate and an angle or a strong channel bar instead of the ordinary bulb-angle beam. At the hatch ends, the coaming plates were carried down over the beam to the top of the bulb and securely riveted to it with a double row of rivets. Instead of the fore-and-aft hatch coaming plates extending from the deck only to their prescribed height, these were carried down well past the ends of all the half beams or were flanged around the bottoms of the beams. *Titanic*'s hatch corners were rounded and the coamings were continuous all around the hatchways; the separate plates which made up the coamings were connected by double riveted butt straps. These hatch coamings were made of stout plates, $^{8}/_{20}$ or $^{10}/_{20}$in thick. The hatch coamings were formed into a strong, rigid girder framework that was well connected to the main structure of the ship at the hatch ends. Additional transverse stiffness was afforded by the introduction of portable transverse web plates between the coamings. The details of *Titanic*'s cargo hatches, as well as the structural details of the various casings and other large openings are addressed later in this volume.

Pillars

Titanic's design utilized a massive number of pillars – solid, vertical support posts – to support the transverse beams through a set of longitudinal girders. In pillaring a vessel, it was important to see that the heads and heels were properly constructed. The formation of the pillar heads and feet were designed so that any thrust or compressive stress would be transmitted directly through the middle of the pillar and not on one side; the pillar head had to bear hard against the beam or girder so that the stress would be borne by the material in the pillar and not by the rivets. With such a formation of heads and feet, the rivets were only subject to stress when tensile strains were endured, such when forces reversed and the pillar acted as a tie rod. Proper pillaring of a ship ensured that the pillars did not act as independent struts or ties, but instead acted in unison with the neighboring pillars and frames.

Generally speaking, there were four longitudinal girders which were fitted beneath the beams of each deck on *Titanic*; these ran continuously for much of the full length of the ship. Through these girders, the support provided by the pillars was more widely distributed to the surrounding beams, rather than supporting only the beam beneath which each pillar was fixed. The girders were built-up, and were made from double 6in x 4in x 0.60in-thick angles to form the outer pair of girders, and by a 7in x 3½in x 0.60in angle back-to-back with a bulb angle 8in x 3½in x 0.60in thick to form the inner pair. The inboard girders were located generally in line with the sides of the casings through the midbody, about 10ft outboard of the centerline. The outboard girders were located at varying distances of up to 31ft outboard of the centerline, this distance being dictated by the internal arrangements of the passenger and crew accommodations and working spaces, and, towards the ends of the ship, the increasing fineness of the hull.

Intercostals were fitted between the beams above each girder, and were riveted to both the girder and to the underside of the deck. The intercostals of the inboard girders were made of plate brackets which were sandwiched between the bulb-angle bars and plain-angle bars and then riveted through, with the upper end connected to the deck above through an angle lug. For the outboard girders, the intercostals between the deck beams were made from channel bar, while a short angle lug connected the web of each deck beam to the top of the girder. Such a system of fitting substantial girders to beams and deck, especially when bracketed to the casings and to the bulkheads at the end of each hold compartment, afforded great support and stiffness to the deck and permitted the pillars within the holds to be spaced much more widely than was usual.

Two basic designs of pillars were used aboard *Titanic* to support beams and girders. One type of pillar, used largely in the machinery spaces and also at the extreme ends of the 'tween deck spaces, was termed a 'built-up column'. Made of stout steel plates rolled into a circular form and riveted together like a mast, these were fitted in combination with other structural features in order to dispense with the numerous round solid iron pillars employed elsewhere. The deck girders in these areas were increased in strength to suit the longer span. As the ship narrowed at the ends, the number of pillars was reduced. On the lines of the girders and columns, the deck plates were increased in thickness. The areas of the ship not supported by built-up columns were supported by solid cast-steel stanchions that varied in diameter and spacing.

The stanchions supporting *Titanic*'s athwartship beams were generally spaced on alternate frames in a fore-and-aft line beneath the girders. Extra pillars and beams were added as needed, such as in areas where there were large openings in the deck.

The sizes of the stanchions beneath each of the decks from the Bridge Deck (B) downwards generally were as follows:

Beneath Bridge Deck (B) 3in diameter; spaced on alternate frames or as required.

Beneath Shelter Deck (C) 4in diameter on every third frame or as required within First Class Reception Room and in first and second class Dining Saloons; elsewhere 3⅜in diameter, reduced at ends of vessel; on alternate frames or as required.

Beneath Saloon Deck (D) 3¾in diameter, reduced at ends of vessel; spaced on alternate frames or as required.

Beneath Upper Deck (E) 5¼in inboard beneath boiler casings, stepped on strong beams at Lower Deck level; 4¼in diameter outside of casings, reduced at ends of vessel; spaced on alternate frames or as required.

Beneath Middle Deck (F) 4¾in diameter outboard within boiler casings, stepped on strong beams at Lower Deck (G) level; 4¾in diameter outside of casings, reduced at ends of vessel; spaced on alternate frames or as required. 16in diameter built-up columns at ends of ship, reduced to 14in at extreme ends and outboard of Squash Racquet Court.

Beneath Lower Deck (G) 6½in diameter in boiler rooms; 4¾in diameter outside boiler rooms, reduced at ends of vessel, spaced on alternate frames or as required; 21in diameter built-up columns forward and 18in aft at ends of ship, reduced to 16in at extreme ends.

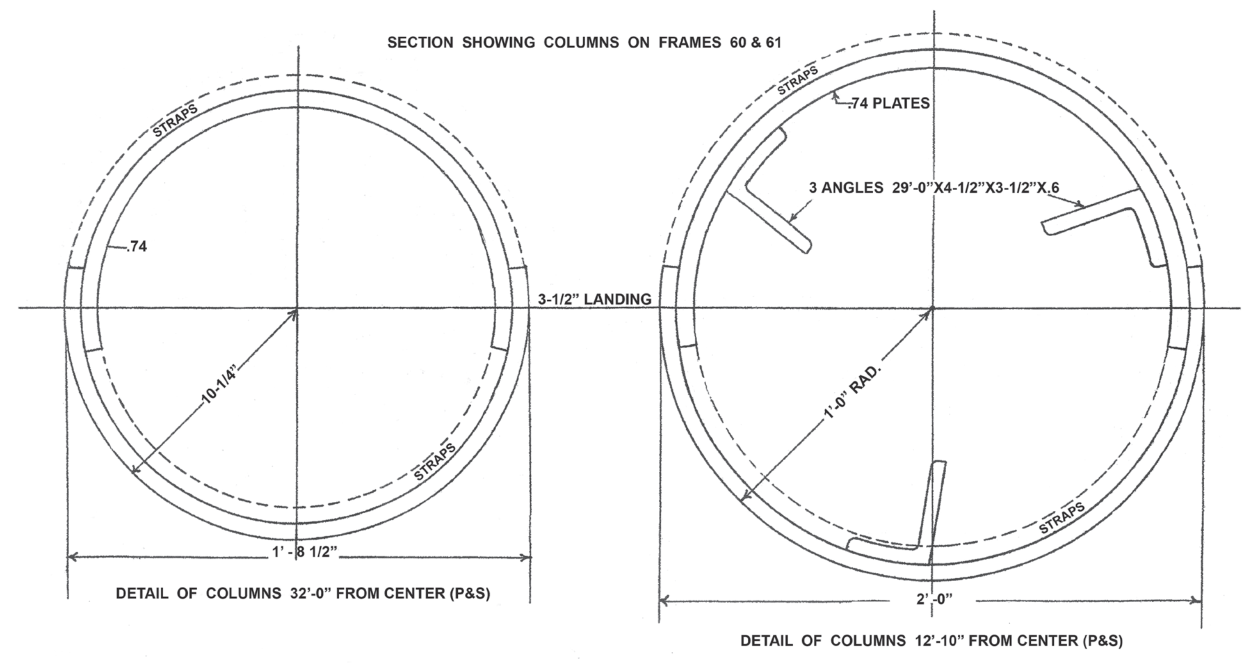
Beneath Orlop and Lower Orlop Decks 21in diameter built-up columns forward and 18in aft at ends of ship; forward columns reduced to 18in at extreme forward end.

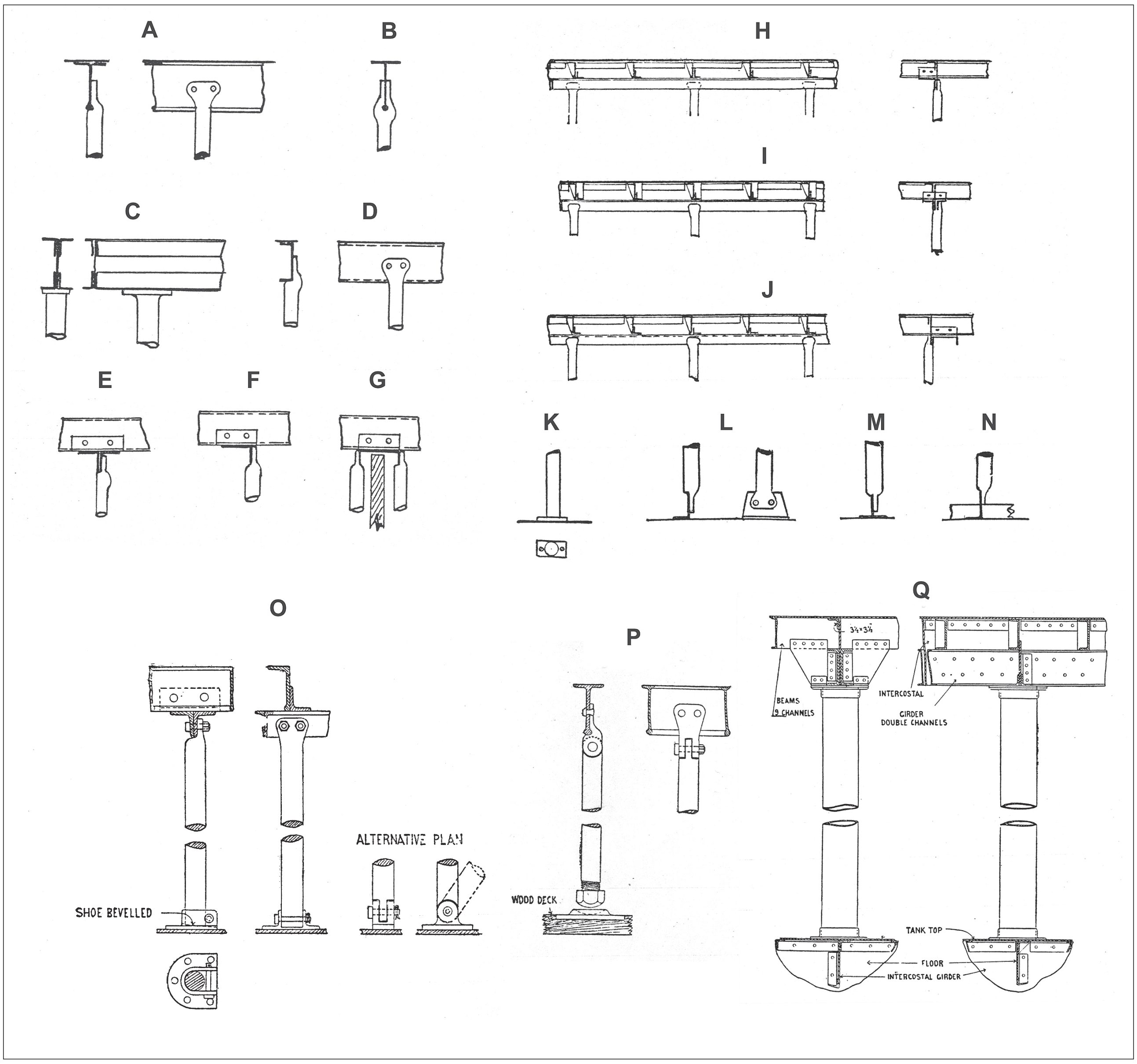
Within Machinery Spaces See next section.

The athwartship pillar spacing was dictated by the spacing of the longitudinal girders beneath each deck as noted above, except in the machinery areas where special consideration was given. Elsewhere, additional pillars were introduced under all permanent heavy deck weights such as the windlasses, capstans, winches and deckhouses. Two or more were generally placed athwartship under each deck weight.

Columns and stanchions in way of engine and boiler rooms

Owing to the large openings above the machinery and boiler spaces, it was necessary to adopt a different treatment in the transverse and longitudinal stiffening of the ship at these points. In the case of the engine spaces, a wide variety of girders and columns were used. The Reciprocating Engine Room began at frame 30A and continued aft to frame 53A, a distance of 69ft. Two lines of longitudinal girders, one above the other, were fitted in the centerline of the ship. The bottoms of the lower and upper girders were 25ft 6½in and 46ft 4½in respectively above the thickest plates of the Tank Top within this compartment. The upper girder beneath the Saloon Deck (D) was of the plate type, with heavy flanges, while the lower girder was built from double 15in channels. These girders were carried at each end on heavy, built-up brackets, while three intermediate columns 15in in diameter, placed along the centerline of the Engine Room at frames 36A, 41A and 46A, supported the girders along their length. Transverse beams formed of double 15in channels extended from the centerline girders at both levels to port and starboard. Beneath the Saloon Deck (D), these beams were located on the same athwartship centers as, and were supported directly by, the central columns. At the intermediate level, the beams were centered 1ft 1½in aft of the column centers, and were connected to the columns and to the centerline girder at this level both above and below through heavy gusset plates and lugs. The outboard ends of the 15in double channel beams at the Saloon Deck (D) level were carried to the sides of the vessel where they were attached through web frames to the sides of the hull. At the intermediate level, the beams were connected to the sides of the casing 3ft 6in above the Lower Deck (G) level through 7ft-deep webs on the outboard sides, and to the inboard sides through heavy brackets. From there, the load was transmitted to the bottom structure through longitudinal double angle girders resting on heavy, built-up columns 12in in diameter. The outboard ends of the intermediate level beams were structurally tied to the sides of the ship through deck beams at the Middle Deck (F) level which were cranked aft of their respective frame locations and attached to the tops of the 7ft-deep webs at the casing sides. The 12in columns were placed, port and starboard, at the same intervals as the centerline columns, 28ft from the centerline of the ship.


SECTION SHOWING COLUMNS ON FRAMES 60 & 61
STRAPS
.74
3-1/2" LANDING
10-1/4"
STRAPS
1' - 8 1/2"
DETAIL OF COLUMNS 32'-0" FROM CENTER (P&S)
STRAPS
.74 PLATES
3 ANGLES 29'-0"X4-1/2"X3-1/2"X.6
1'-0" RAD.
STRAPS
2'-0"
DETAIL OF COLUMNS 12'-10" FROM CENTER (P&S)


A
B
H
I
C
D
J
E
F
G
K
L
M
N
O
P
Q
ALTERNATIVE PLAN
SHOE BEVELLED
WOOD DECK
3½×3½"
BEAMS
9 CHANNELS
INTERCOSTAL
GIRDER
DOUBLE CHANNELS
TANK TOP
FLOOR
INTERCOSTAL GIRDER

The Turbine Engine Room, located between frames 53A and 71A, also received special treatment, partly because the turbine was in the centerline of the ship and partly because it was possible, owing to the lesser height of the turbine as compared to the reciprocating engines, to continue the Upper Deck (E) over the Turbine Engine Room. To support this deck, there were two 24in-diameter columns fitted at frame 60A, centered 12ft 10in from the centerline of the ship port and starboard. These two columns also supported two transverse beams formed from double 15in channels, which extended the full width of the Turbine Engine Room at the Middle Deck (F) level. The transverse beams were situated with the after beam centered on frame 60A and the forward beam on frame 59A; they were each supported at the columns by single sets of upper and lower bracket plates designed to handle them both. At the Lower Deck level, 32ft from the centerline at frame 61A, a girder was fitted on both port and starboard sides and supported on 20½in-diameter columns.

In the boiler rooms there was a line of four cast-iron stanchions 6½in in diameter, placed athwartship in the spaces between the boilers. In the case of the two inner rows, the stanchions were splayed at the foot creating an inverted 'Y', the legs of which consisted of two 4⅛in-

Opposite, above Fig. 4-19 **Built-Up Columns in Engine Rooms** – Sections through the built-up columns from Frames 60A and 61A in the Turbine Engine Room; the built-up columns employed in the Reciprocating Engine Room were similarly formed. *(Illustration by Bruce Beveridge based on original H&W Engine Room Columns drawing)*

Opposite, below Fig. 4-20 **Pillar Heads and Heels** – The forms of the heads and heels of pillars were governed by the nature of the part of the vessel to which the connection was made. Figs. A and B illustrate two methods of attachment to T-bulb beams; the first was the usual one, the second was not as common but had the advantage of gripping the beam around the bulb, and so relieved the rivets when the pillar was under tension. Figs. C and D show the connection to H-beams and channel beams respectively. When beams were fitted on every frame, with the pillars being at alternate frames, when the pillars were not fitted directly beneath a girder it was necessary to install runners under the beams in way of the pillars to support the intermediate beams. Figs. E and F show two styles of the beam runner; note that the attachment to the beams is by means of a riveted angle lug; where the beams were of channel section this was unnecessary. Fig. G was a suitable form where the pillars had to be reeled for shifting boards, as was frequently the case with those at the middle line in cargo vessels. The plan adopted was to fit consecutive pillars on opposite flanges of the channel runner, thus forming two lines between which the shifting boards could be reeved. Where intercostals to the deck plating were required, as in the case of quarter pillars to deep tanks, or where pillars were widely spaced, they were fitted in various ways, Figs. H, I and J showing some of these with pillar head attachments. The intercostals transformed the beam runners from simple ties into strong girders able to stiffen the deck and to distribute the stresses.

The heel attachments of pillars were not as varied in form as those of the heads. A common one is shown in Fig. K, consisting of a horizontal shoe forged on to the lower end and through riveted to the deck plating or to the beam, as the case may be. A favorite method when the heel rested on an inner bottom was to rivet a short bulb-angle or tee lug to the plating, and connect the pillar to the vertical flange (see Figs. L and M). This plan was sometimes followed for making attachments to steel decks when the latter were to be wood sheathed, the vertical flanges of the lugs being made deep enough to allow the heel of the pillar to remain above the wood deck (see Fig. N) to facilitate the caulking of the latter at this part.

The end attachments of pillars consisted of at least two ⅜in rivets. When the pillars reached a length of 18ft or a diameter of 4in, the number of rivets at each end was increase to three. Pillars 5in or above in diameter required a four-rivet connection at the ends.

Pillars were frequently required to be portable; in way of the hatches, for example, they were to be removed when loading many kinds of cargo. Bolt-and-nut fastenings were often adopted (see alternative plan in Fig. O), but occasionally, particularly at the heels, these were found impracticable or undesirable, and arrangements such as the fittings in Figs. O and P were resorted to. When fitted in either of these ways a pillar could, of course, only act as a strut.

While several rows of close-ranged pillars were valuable to a vessel in regard to her strength, from the standpoint of cargo stowage they were obviously somewhat of a drawback. With almost all cargoes, the pillars, particularly those in the wings, gave rise to a considerable amount of broken (separated) stowage, and although by splitting up the cargo they prevented damage through side pressure when the vessel was rolling, many owners sought to eliminate them wherever possible. For example, in vessels of a breadth requiring three complete rows of pillars, it was permitted to substitute one complete middle line row with two rows in the wings at wider spacing.

With this modified arrangement, however, beam runners with intercostal attachments at each deck had be fitted in way of each line of quarter pillars, with the scantlings of the intercostals and pillars being governed by the spacing of the pillars, the breadth of deck to be supported and the probable load.

In many instances, even when spaced in this manner, the pillars were still found to be too numerous. In these instances, the center row was dispensed with and a very wide spacing was adopted for the quarter pillars; in some vessels, this resulted in no more than two pillars being fitted per side, even in a long hold. In such cases the decks were supported, and the loads transferred to the pillars by means of specially constructed and reinforced runner girders. Fig. Q illustrates one such arrangement which is similar to that used in *Titanic*'s engine space. These pillars were stepped on the Tank Top at the junction of a floor plate and intercostal girder. This was necessary for rigidity, and when pillars could not be placed in this way, they were supported by means of brackets or on seatings built on the Tank Top.

diameter stanchions. The purpose of the unique design of these stanchions was to provide a passageway between the boilers. These stanchions extended upwards to just beneath the Lower Deck (G) level where they supported 15in double channel beams running the full width of the hull, and located generally on 9ft centers along the length of each boiler room.

Within the casings above the boiler rooms, 5¼in-diameter stanchions rose upwards from the top of

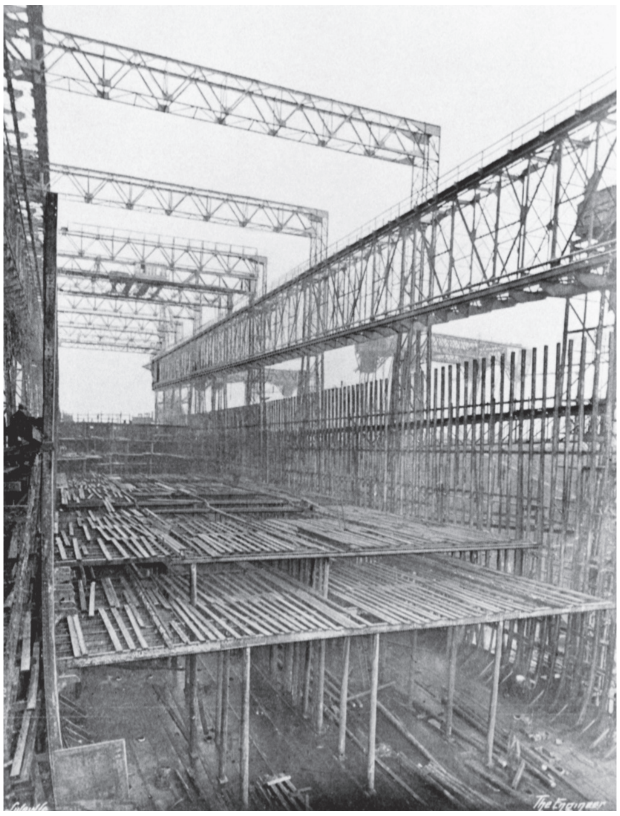


Fig. 4-21 **View Looking Aft From the Gantry Walkway** – *Olympic* in the process of framing. In this view, the vertical transverse frames have been erected as far forward as what will become WTB E at the after end of No.6 Boiler Room. The upper edge of the starboard vertical margin plate of WTB E is visible at the lower left of the image. The beams closest to the camera are at the level of G Deck, while those immediately aft and above are at the level of F Deck. In the distance farther aft, progress is being made in the fitting of beams along E, D and C Decks. Lumber is laid loosely across the open expanses between the beams to allow the ship fitters to move about the rising structure, highlighting the dangers inherent in their work. *(*The Engineer*/Authors' collection)*

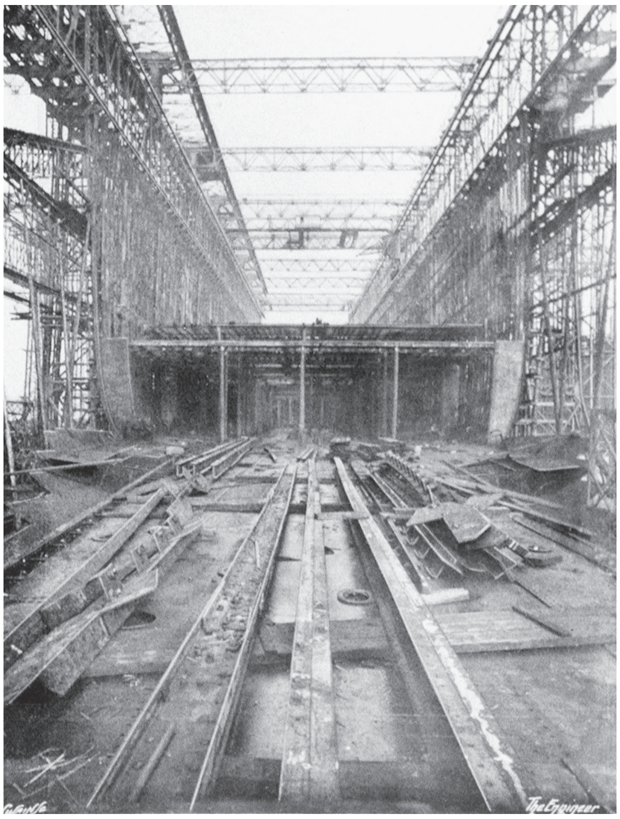


Fig. 4-22 **View Looking Aft From the Tank Top** – A view of progress made on *Olympic*'s framing, looking aft from the forward end of the Tank Top on or shortly after the date of the image in Fig. 4-21. The vertical margin plates of what will become WTB E have already been put in place along with the side framing. Manholes can be seen on the Tank Top in the foreground. *(*The Engineer*/Authors' collection)*

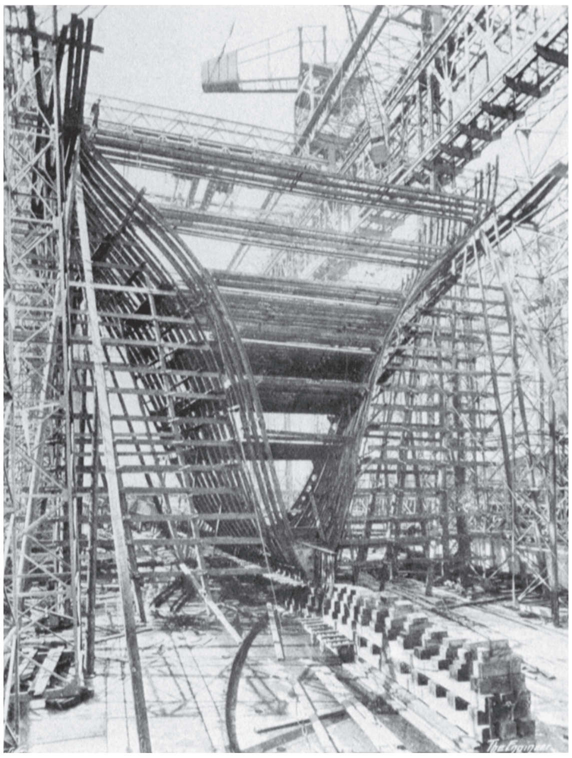


Fig. 4-23 **After End Framing** – The framing begins to rise at *Olympic*'s after end, as viewed looking forward from the end of the slip. *(*The Engineer*/Authors' collection)*

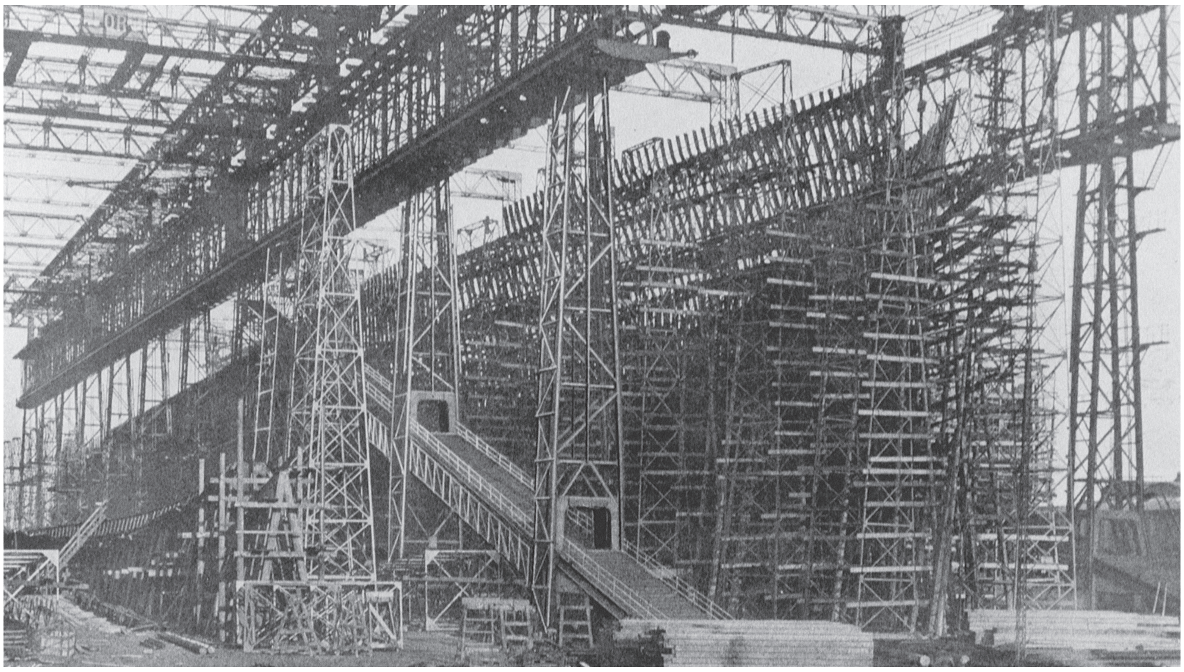


Fig. 4-24 ***Olympic* Nearly Framed** – As *Olympic*'s framing nears completion, progress continues on *Titanic* in the adjacent slip as scaffolding is erected preparatory to raising her frames. *(*The Engineer*/Authors' collection)*

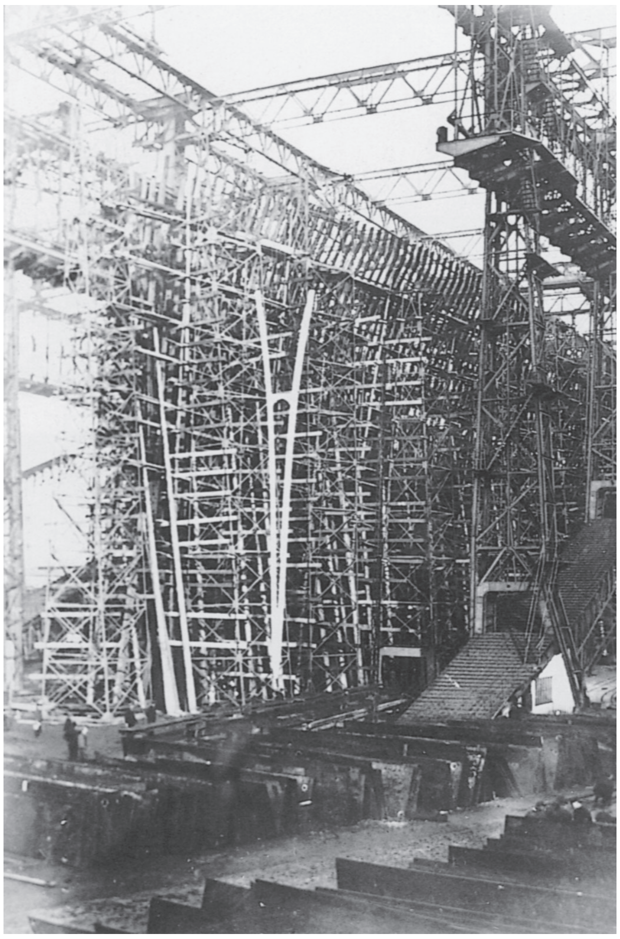


Fig. 4-25 **Lifting the Last Frame** – The white-painted last frame of *Olympic* as it was being raised into place. *(*The Engineer*/Authors' collection)*

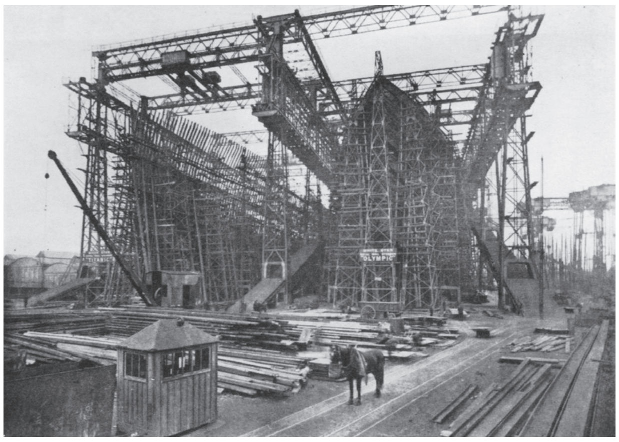


Fig. 4-26 ***Olympic* Plated and *Titanic* Framed** – *(*The Engineer*/Authors' collection)*

the 15in double channel beams to support the inboard girders beneath the Upper Deck. In Boiler Room Nos 1 through 4, a second set of shorter 4¾in-diameter stanchions supported the outboard girders beneath the Middle Deck (F).

Erecting of the frames

After the keel was set in place, the positions of the accompanying transverse frames were marked upon it. The keel was only contiguous with a portion of the frames, as the stern post and stem took up those frames at the extreme ends of the hull.

Once the frames, reverse frames, floor-plates and beams had been prepared, and their accuracy had been verified against the scrive board, they were then carried to a staging area at the stem of the vessel from where they were hoisted into their respective positions indicated upon the keel and given a rake that would bring them perpendicular to the knee. This operation was termed 'plumbing'. The process of adjusting the frames to cross the keel at perfect right angles was called 'horning'. In a vessel with a double bottom like *Titanic*, the double bottom was erected first (usually keel, center through-plate, floors, tank margin plates, and then wing tanks) and then the frame legs were hoisted into position.

Temporary wooden shoring was erected within the rising framework to maintain the proper spacing between the various frames and deck beams while the work of fitting the shell and deck plating proceeded. This shoring was gradually removed as the numerous longitudinal girders and support pillars, columns and stanchions were installed, taking up the internal support of the vessel.

Notes

1. 'Pitch' is the uniform distance apart of rivet holes, rivets, frames, and other uniformly spaced objects along a common line. Except in instances where the precise pattern and location of rivets had to be carefully controlled to meet certain design requirements, the distance between rivet holes (and, by extension, the rivets themselves) was generally expressed in terms of multiples of the diameter of the rivets being installed. For instance, a course of rivets having a diameter of 1in and specified as having a pitch of '4½ diameters' would result in a line of rivets having a uniform spacing of 4½in center-to-center between rivets.
2. 'Joggled plating' is described in Chapter 7 of this volume.

Chapter 5

Stem, Stern Castings and Rudder

Stem

Titanic's stem formed the foremost end of the hull. The castings and bars which formed the stem and forefoot were supplied by the Darlington Forge Company. The stem was straight in form above the load waterline, with a slight rake forward to minimize the effect of a collision, and to overcome the appearance of 'falling aft' at the head, which was the usual look of a completely vertical stem.

The stem was fabricated from rolled bar of rectangular section in five segments totaling 7¼ tons. A 3½-ton, cast-steel forefoot of hollow section at the lower end connected the stem to the keel plate. These sections were connected to one another through 2ft 6in-long scarfs using flush rivets. Fabrication of the stem in segments eliminated many handling and construction difficulties and reduced the costs of repairs in the event of damage. The breadth and depth of the stem bar was 3in x 13½in at the bottom above the load waterline and gradually decreased to 3in x 10in at the stem head. A special feature of *Titanic*'s stem was the addition of a cast-steel hawse pipe inserted into the upper portion of the stem bar. This casting weighed 700lb and was intended to take a steel-wire hawser provided for towing and for use with the center bower anchor.

In essence, the stem was a continuation of the flat keel. The lower part of the stem was carried on to the fore length of the keel and was securely riveted to intercostal plates, which in turn were riveted to the adjoining floors. The lower ends of the frames in this vicinity extended below the top of the stem, and the fore end of the keel plate was dished (made concave in section) to permit it to come under the stem while still faying against the ship's sides. The keel plate, for all intents and purposes, ended where it rose on to the sides of the forefoot and terminated in the form of a 'dropped strake' immediately ahead of frame 118F. The keel plate was dished around the after part of the forefoot casting, overlapping it a distance of approximately 2ft. Forward of this point, it became an ordinary strake of shell plating, being picked up and continued by a 'stealer' plate in strake 'D'. Thus, the keel plate was lifted on the side of the stem and through-riveted to it. Through-riveting was also adopted at the after end of the stem. The center keelson plate was carried forward intercostally and attached to a tongue formed on the stem.

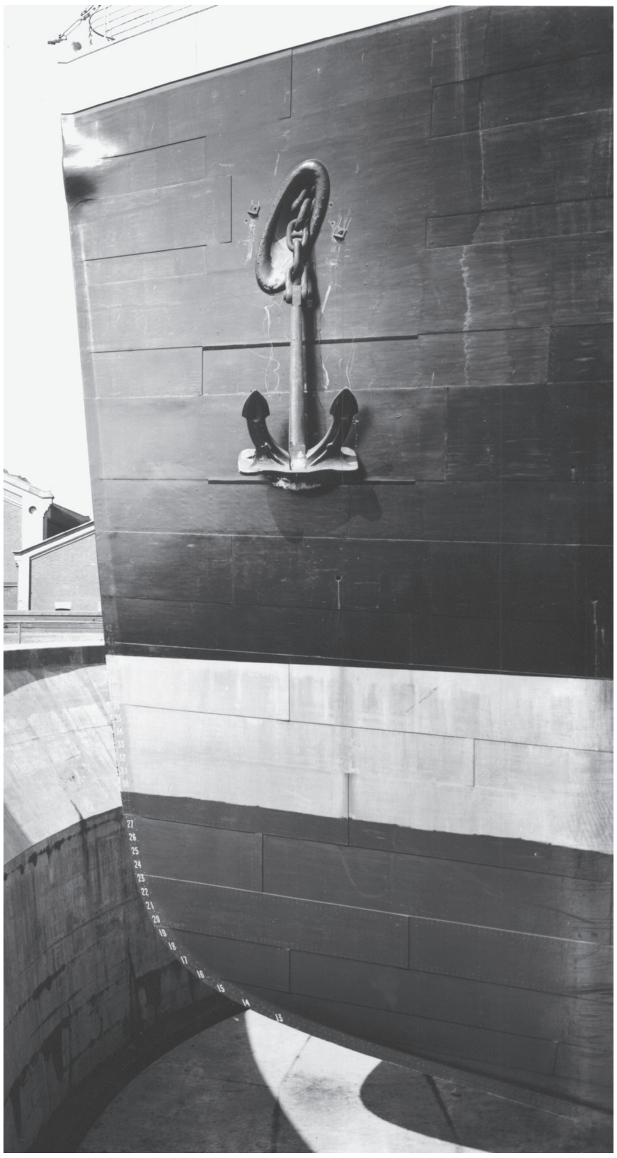
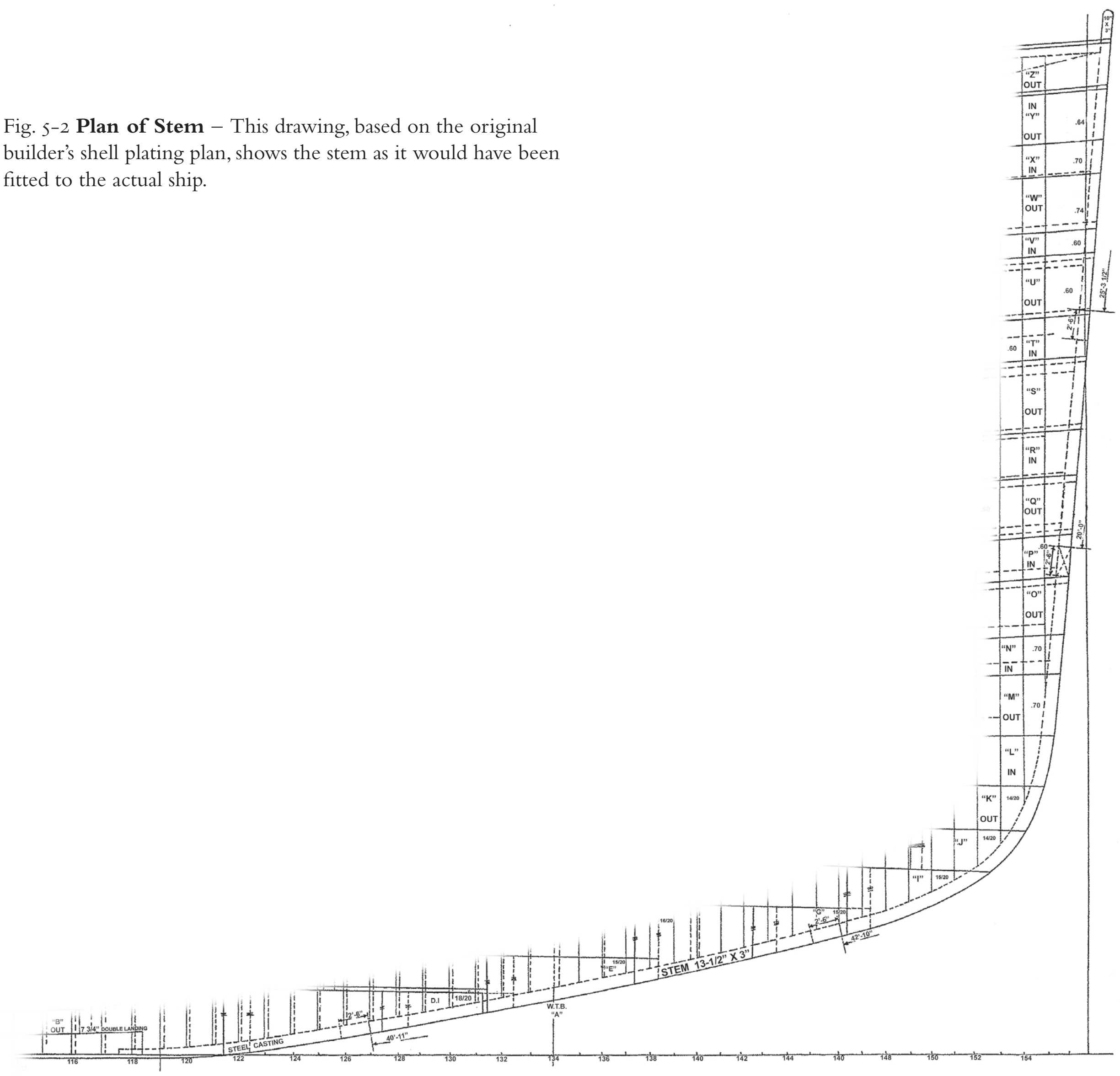


Fig. 5-1 ***Olympic* Bow, Port View** – *Olympic* in drydock showing her straight stem. *(H&W/Authors' collection)*

Fig. 5-2 **Plan of Stem** – This drawing, based on the original builder's shell plating plan, shows the stem as it would have been fitted to the actual ship.


"Z"
OUT
IN
"Y"
.64
OUT
"X"
IN
.70
"W"
OUT
.74
"V"
IN
.60
"U"
OUT
.60
22'-3 1/2"
2'-6"
.60
"T"
IN
"S"
OUT
"R"
IN
"Q"
OUT
26'-0"
"P"
IN
.60
2'-6"
"O"
OUT
"N"
IN
.70
"M"
OUT
.70
"L"
IN
"K"
OUT
14/20
"J"
14/20
"I"
15/20
"G"
15/20
2'-6"
42'-10"
16/20
15/20
"E"
STEM 13-1/2" X 3"
D.I
18/20
2'-6"
40'-11"
W.T.B.
"A"
STEEL CASTING
"B"
OUT
7 3/4" DOUBLE LANDING
116
118
120
122
124
126
128
130
132
134
136
138
140
142
144
140
148
150
152
154

The stem was thoroughly bound with the structure by the main shell plating. The strakes at their forward ends were arranged to lap on each side of the stem, and rivets sufficient in length to extend through all three thicknesses were employed. The shell plating was kept back at least ½in from the forward edge of the stem to protect the caulking. Two rows of rivets spaced at 5 diameters center to center, followed by a third row on approximately twice this spacing aft of the first two rows, connected the shell plating to the stem.

Stern frame and boss castings

The function of the stern frame was to provide support to the rudder, center shaft boss and tail end shaft, and to frame the aperture in which the center propeller revolved. The principal parts of the stern frame were an after or rudder post (the 'stern post') which held the gudgeons and bushings in which the rudder pintles rode, and a propeller post which incorporated an enlarged or 'bossed' area through which the center tail shaft and stern tube passed to carry the center propeller. The castings forming *Titanic*'s stern frame were of massive construction. The size and strength of these castings were necessitated not only by the huge size of the vessel, but by the enormous stresses to be borne by these castings. With the lower portion of the rudder post standing free of the hull, it had to be strong enough to withstand both the weight and the side forces generated by the rudder, as well as being sturdy enough to resist damage should the stern of the ship become grounded. Additionally, the stern frame and its connections had to resist the constant vibration caused by the propellers without succumbing to fatigue or loosening of the joints.

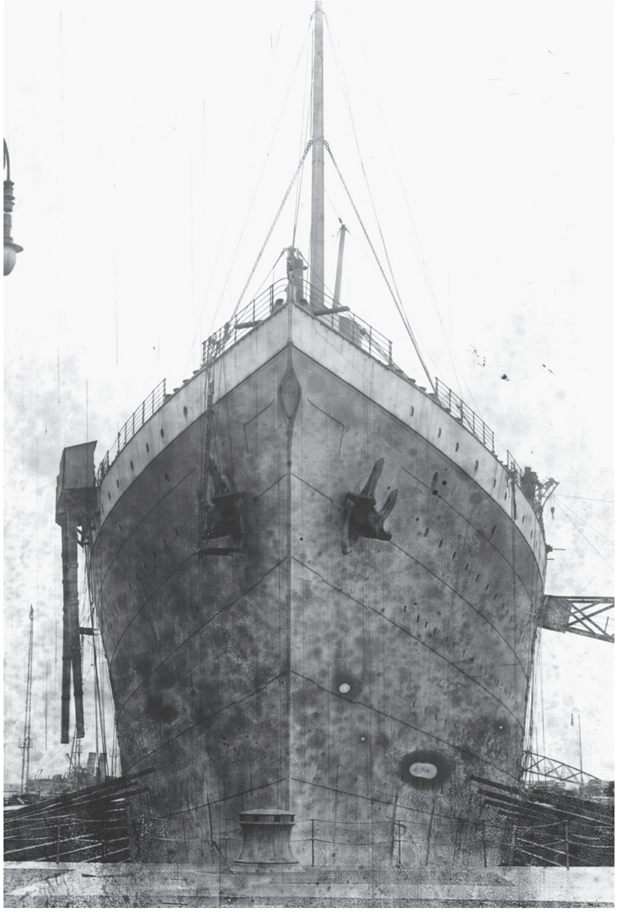


Fig. 5-3 ***Titanic* in Drydock** – A view of *Titanic* in drydock looking straight on at her stem. The cast-steel hawse pipe is seen with a wooden cover inserted.

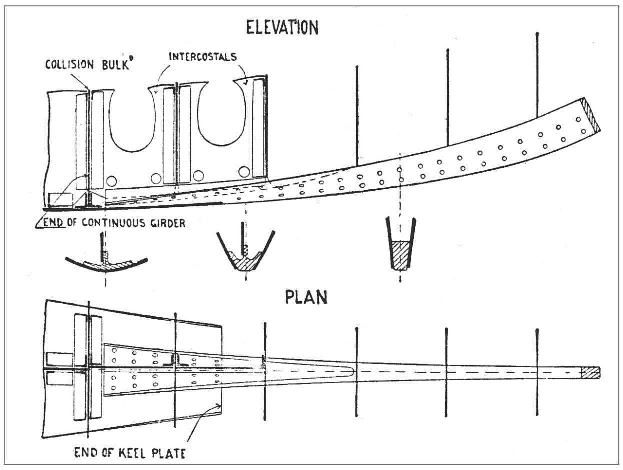

ELEVATION
COLLISION BULK'D
INTERCOSTALS
END OF CONTINUOUS GIRDER
PLAN
END OF KEEL PLATE

Fig. 5-4 **Keel Connection at Stem** – This drawing is of the lower stem of a common cargo steamer, but depicts the type of connection utilized to join the keel plating and stem on *Titanic* (though obviously, this one is not as massive).

Titanic's rudder, stern frame and boss arm brackets for the wing propellers were designed by Harland & Wolff, but the job of producing the enormous castings was entrusted to the Darlington Forge Company, an outside firm which had a great deal of experience in this field. The castings were all of Siemens–Martin mild cast steel with the exception of the rudder stock, which was of forged ingot steel. The castings were ordered by full-size patterns made to the lines on the Mold Loft floor.

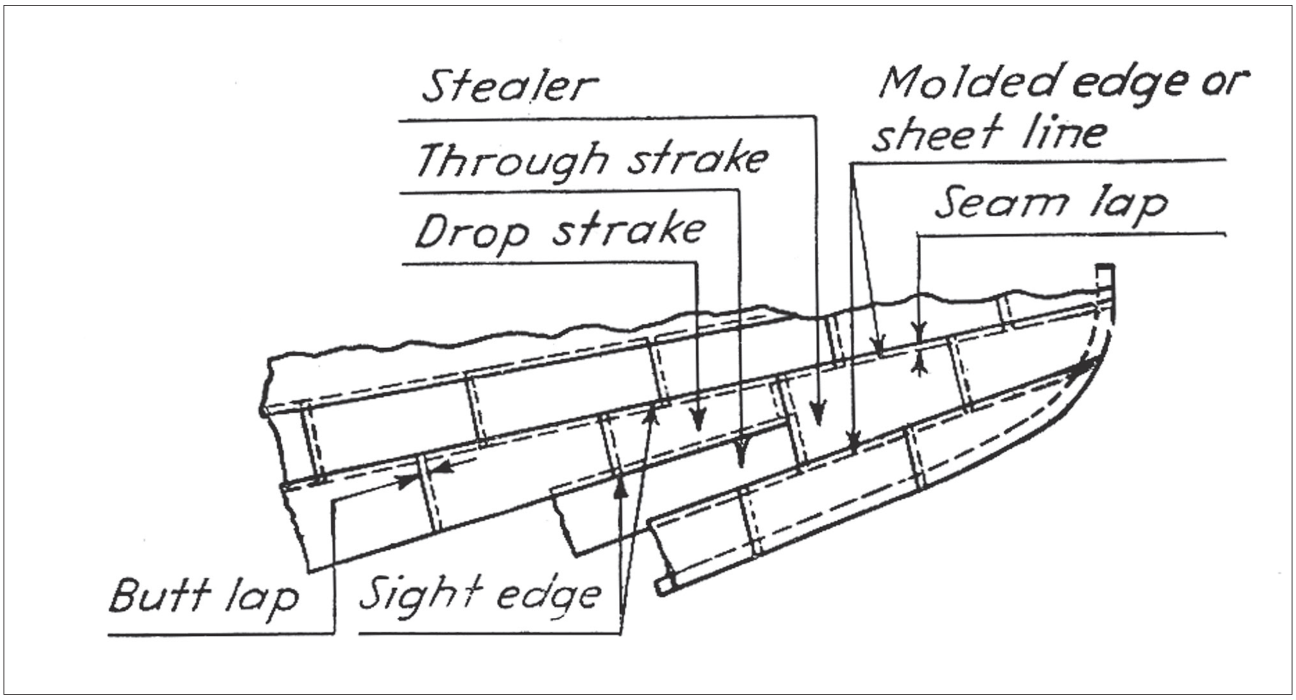

Stealer
Through strake
Drop strake
Molded edge or sheet line
Seam lap
Butt lap
Sight edge

Fig. 5-5 **Method of Dropping Plate Strakes** – This diagram demonstrates how the shipbuilders dropped, or 'deleted,' excess strakes as they narrowed near the ends of the vessel. Shown in this illustration is the bow in the region where the strakes of plates meet near the lower end of the stem bar.

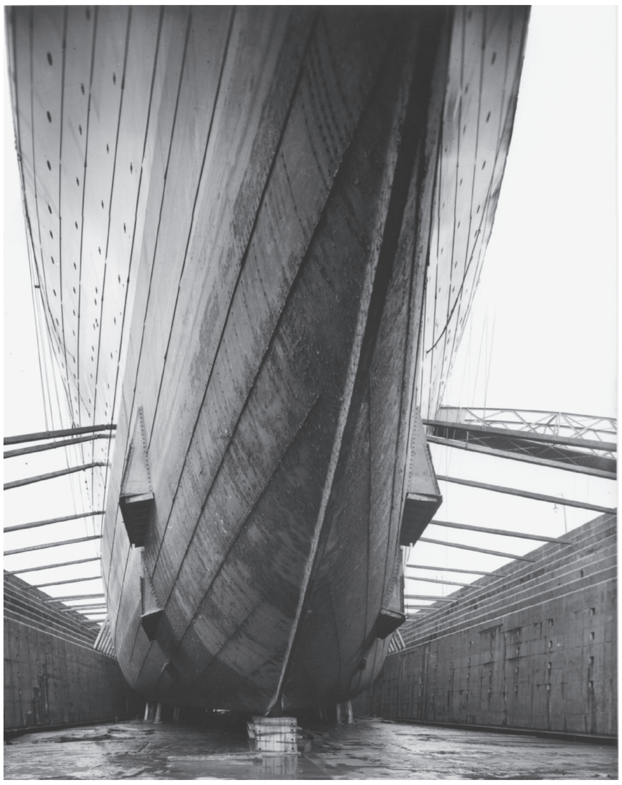


Fig. 5-6 ***Olympic* in the Graving Dock** – This image, taken from the bottom of the Graving Dock, shows the transition of the stem into the keel plate. The dropped strakes and stealer plates in this area can also be seen. *(H&W/Authors' collection)*

Great care was exercised in the manufacture of the stern frame. The castings had to be as free as possible from any excessive elements known to produce brittleness such as blowholes and cavities. The bores into which the stern tubes were installed were roughly bored before the stern frame and propeller brackets were sent to the shipyard. However, it was only after the castings were permanently installed in the ship and all of the surrounding structure completed that the exact alignment of the shafts could be determined, after which the holes were accurately line-bored to finished size.

When an entire stern frame was cast in one piece, the difficulty, labor, and expense, not to mention loss of time incurred in extricating a broken stern frame from a hull, was enormous. When a vessel was trimmed by the stern, it was not uncommon for the aftermost extremity of the keel, formed by the base of the stern frame, to touch bottom in shallow water. This sometimes resulted in a fractured stern frame, the break usually occurring at the bottom of the propeller aperture. In some cases, by fitting a 'shoe strap', a stern frame could be repaired well enough to permit its continued use. In other cases, where the damage had been more extensive, the whole stern frame had to be renewed. To obviate this, stern frames were constructed in separate pieces connected by scarfs. The two-piece design was common at the time, especially in large vessels. Unfortunately, all of the advantages afforded by this design were completely negated when a collision occurring in New York between *Olympic* and the Bermuda-bound Furness liner *Fort St George* resulted in such significant damage to the lower extremity of *Olympic*'s stern frame that Harland & Wolff found it necessary to replace the stern frame in its entirety.

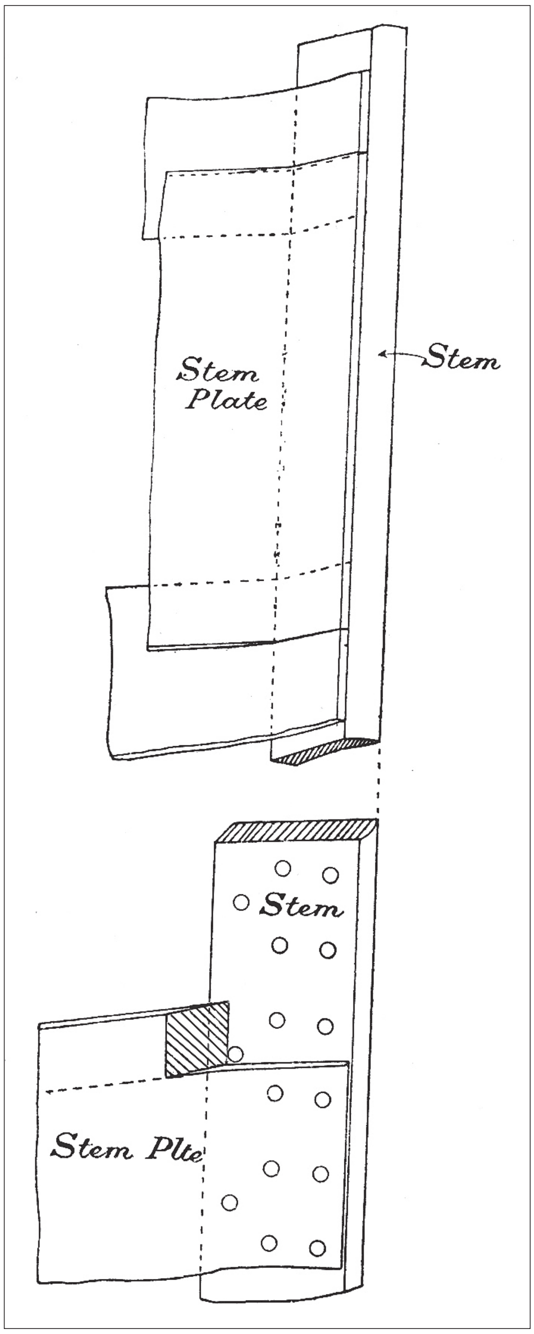


Fig. 5-7 **Riveting Through Shell Plates and Stem Bar** – This drawing shows how the plating was fitted and riveted to the stem of *Titanic*. Rivets were inserted through all three thicknesses.

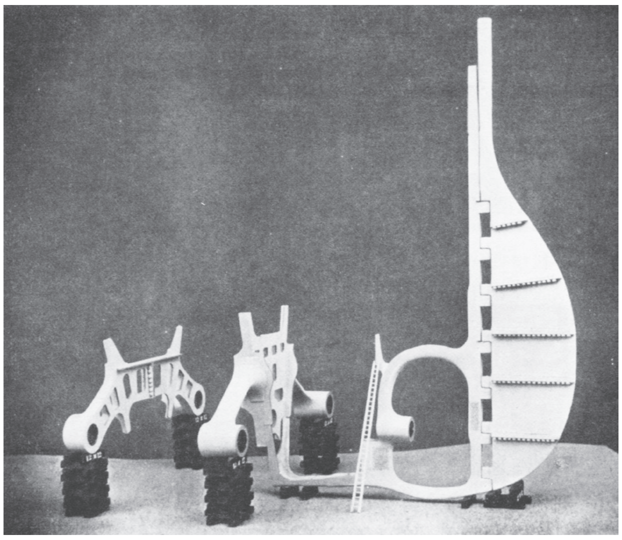


Fig. 5-8 **Arrangement of Stern Castings** – A builder's model showing the arrangement of the stern castings and rudder. *(*The Shipbuilder*/Authors' collection)*

Titanic's stern frame was of 18in x 11in dished section, increased to 21in x 11in below the Lower Deck (G) level, with the stern post in way of the propeller aperture being solid. The casting was made in two pieces which were connected through a specially designed arrangement of scarfs, with one being on the stern post and the other on the forward post immediately beneath the 3ft 10in-diameter center propeller boss. The top of the stern frame casting stood 68ft 3in above the base line, while the overall length excluding the gudgeons measured 37ft 4in. A large palm was provided at the forward end to form a strong connection to the after boss arm casting and the main structure of the vessel. The scarfs were connected with Lowmoor iron rivets 2in in diameter; fifty-nine of these rivets were used in the forward and fifty-three in the after scarf, having a total weight in excess of 1 ton. The great care exercised in fitting these rivets to ensure a strong connection was evidenced by the fact that the holes through the scarfs were match-drilled to finished size, while the rivets were all precision-turned and fitted, and then specially closed with rams.

A considerable amount of wear and tear took place on the stern frame owing to the incessant wearing by the rudder's movements when the vessel was under way. In order to reduce the expense and time involved in renewing worn pivoting and load-bearing surfaces, *Titanic*'s gudgeons were lined with removable gunmetal bushings. A hardened nickel-steel cup having a conical depression was placed at the bottom of each bore to bear the weight of the rudder. This enabled the rudder to work more smoothly and the parts, when worn, could easily be replaced without excessive difficulty or expense.

The two wing (reciprocating engine) propeller shafts were carried by separate propeller bracket castings, around which the shell plating was carried to form 'bossings'. In order to accommodate the wing shafts, the framing of the ship was bossed for a length of 80ft from the stern. The after propeller brackets were mild steel castings of hollow section. Comprised of two pieces, they were connected at the centerline by seventeen 2in turned and fitted bolts and attached to the vessel by strong, deep flanges to form a continuous web right across the ship.

This web, in turn, was riveted to a 2in steel plate of special quality extending from side to side of the vessel. These immense castings were fitted to the stern frame,

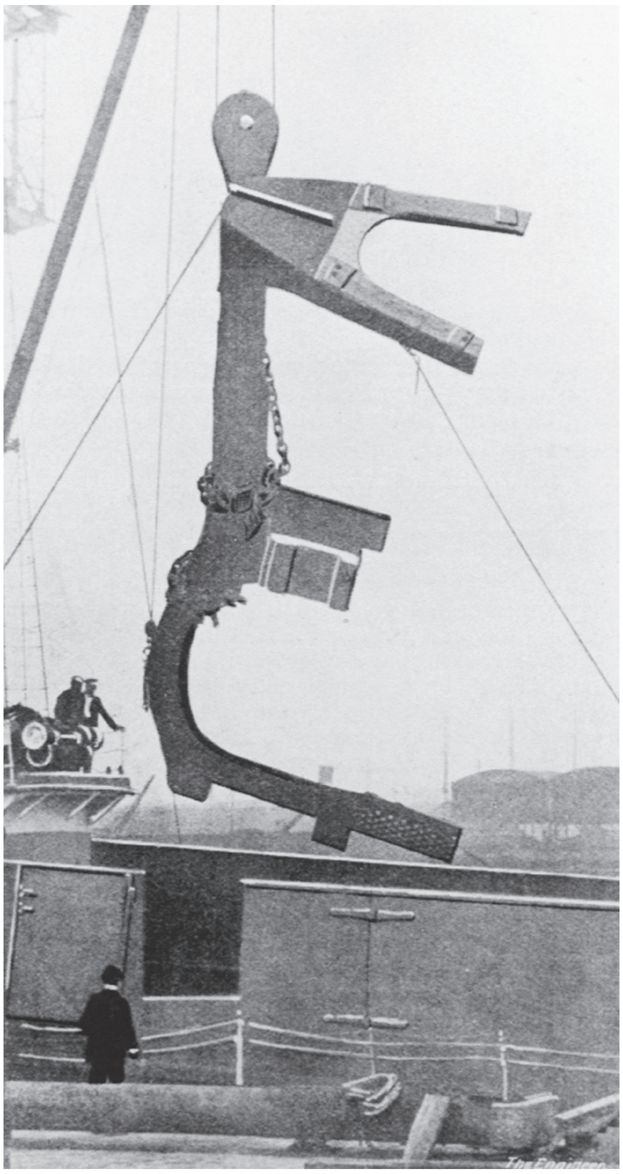


Fig. 5-9 **Lower Portion of Stern Frame on *Olympic*** – The V-shaped palm which connected this piece to the after shaft brackets is plainly visible. *(*The Engineer*/Authors' collection)*

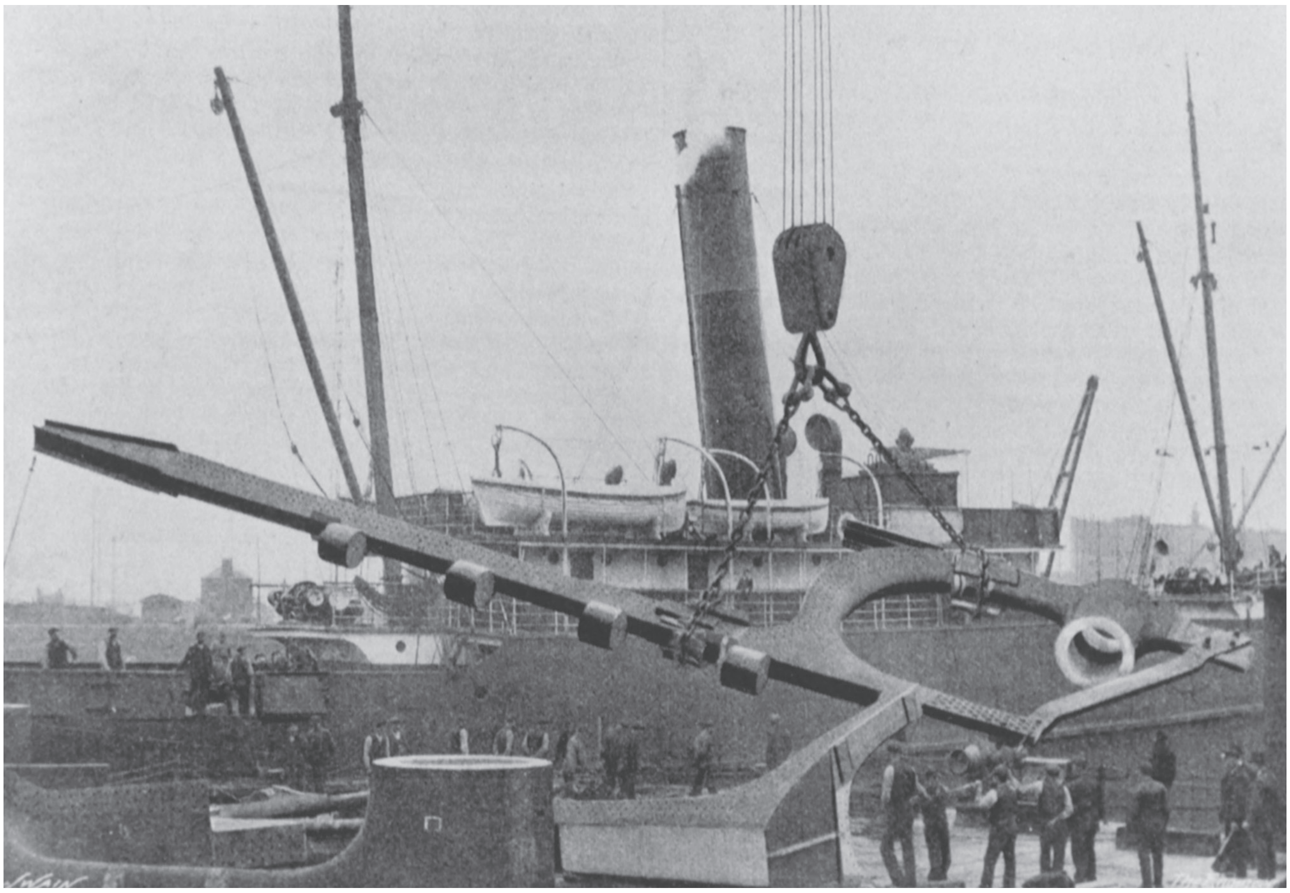


Fig. 5-10 **Upper Portion of Stern Frame on *Olympic*** – Visible at left are the attachment point for the rudder trunk and the flanges which attach the top of the casting to the transom floors; at right are the upper arch of the propeller aperture, center shaft boss and upper propeller post; in the middle can be seen five of the seven stern post gudgeons. Note the temporary brace bolted between the propeller and the rudder posts to prevent these features being bent out of alignment during transport. *(*The Engineer*/Authors' collection)*

shell plating, floors and framing of the ship by rivets. The center-to-center span of the wing shafts at their point of exit from the bosses on the after brackets was approximately 39ft; the outside diameter of the wing bosses at their after ends was 4ft 10in.

At this point the introduction of a forward set of brackets as a means of increasing the strength of the ship is worth noting. The two arms were made in separate pieces of the girder cross-section and connected by fourteen 2in turned and fitted bolts at the centerline of the ship, the whole then being securely attached to the ship's plating and framing. Particular attention was paid to the angle of these boss-arms, in order to ensure that the flow of water to the center propeller would be as free from turbulence as possible so it would rotate in solid water.

The particulars of the stern castings were as follows:

Stern frame (two pieces)

Weight	70 tons
Height	67ft ½in
Length of keel-post	37ft 4in
Section of stern post (maximum)	21in x 11in
Palm at forward end (approximate)	9ft wide x 11ft high

After brackets (two pieces)

Weight	73¾ tons
Width outboard from centerline, each	22ft 0in
Distance between shaft centers at forward end of bosses	38ft 10¾in
Depth of bosses	6ft 3½in
Diameter of bosses at forward ends	5ft 2¼in

Forward brackets (two pieces)

Weight	45 tons
Width outboard from centerline, each	22ft 3⁹⁄₁₆ in
Distance between shaft centers at forward end of bosses	38ft 5⅜in
Depth of bosses	3ft 6½in
Diameter of bosses at forward ends	6ft 2in

While the stern frame castings were designed to be exceptionally strong in and of themselves, the design of the connections to the shell plating and framing were equally important. The integrity of these connections was ensured in the following ways:

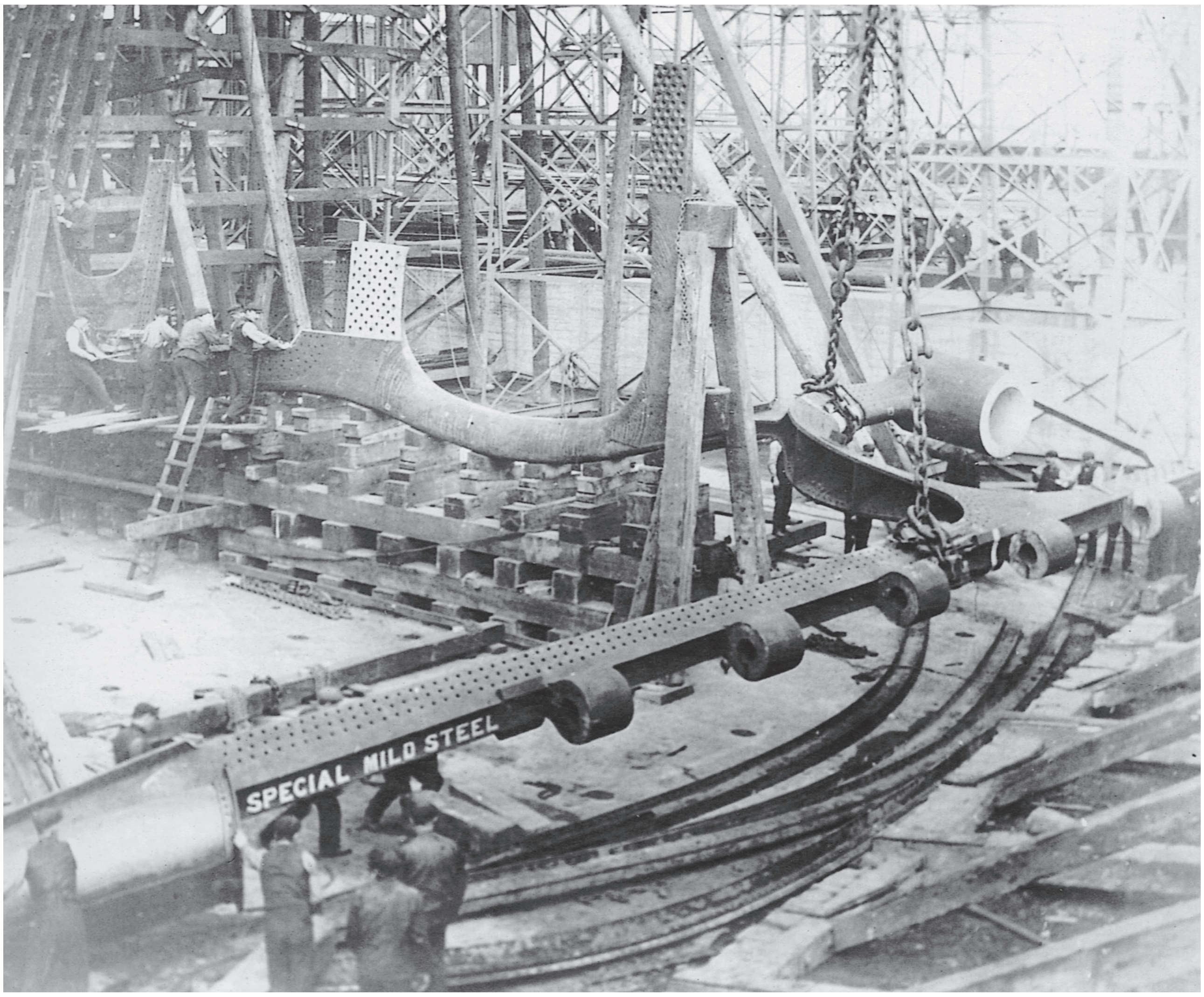


Fig. 5-11 **Two Sections of the Stern Frame** – The lower section of *Olympic*'s stern frame is in place, and the upper portion is being readied for installation. On the lower section, the vertical surfaces with the multitude of closely-grouped holes in them are the lower halves of scarfs which will be used to connect the two pieces together. At the lower left, workers have recently finished attaching the rudder trunk. *(*The Engineer*/Authors' collection)*

(1) By carrying up the stern post (rudder post) to a height sufficient to enable a good connection to be made to a thick plate called a transom floor. The transom floor was, in reality, a heavily constructed, non-watertight bulkhead which extended from side to side of the vessel above the counter on the fore side of the post. *Titanic*'s transom floors ran from the transom frames to the underside of the Shelter Deck (C) and were heavily braced and reinforced with numerous gusset plates and web frames.

(2) By ensuring that the propeller post extended to a height sufficient to enable a good connection to be made to another deep transom or floor plate. The rudder and propeller posts were connected to their respective transom plates. The propeller post had a projecting 'palm' which was solidly riveted to the aft side of a heavy 1.24in-thick plate floor fitted between the frames at 141A. The top of the stern frame was solidly riveted to built-up brackets connected to the transom floors.

(3) By ensuring that the lower part of the stern frame, which projected forward of the propeller post, had a solid connection to the rest of the ship's structure. The portion of the stern frame forward of the propeller post was of dished section, terminating in a forked, V-shaped palm which connected to the base of the after bracket casting and the main structure of the ship. Transverse webs were cast into the lower dished section at each frame to allow deep floors and the lower extremities of the frames to be solidly connected to the casting. The entire area from the propeller post forward to the after brackets was stiffened by transverse deep floors on each frame, running from the bottom to the tunnel stringers at the height of the Orlop Deck. A further longitudinal

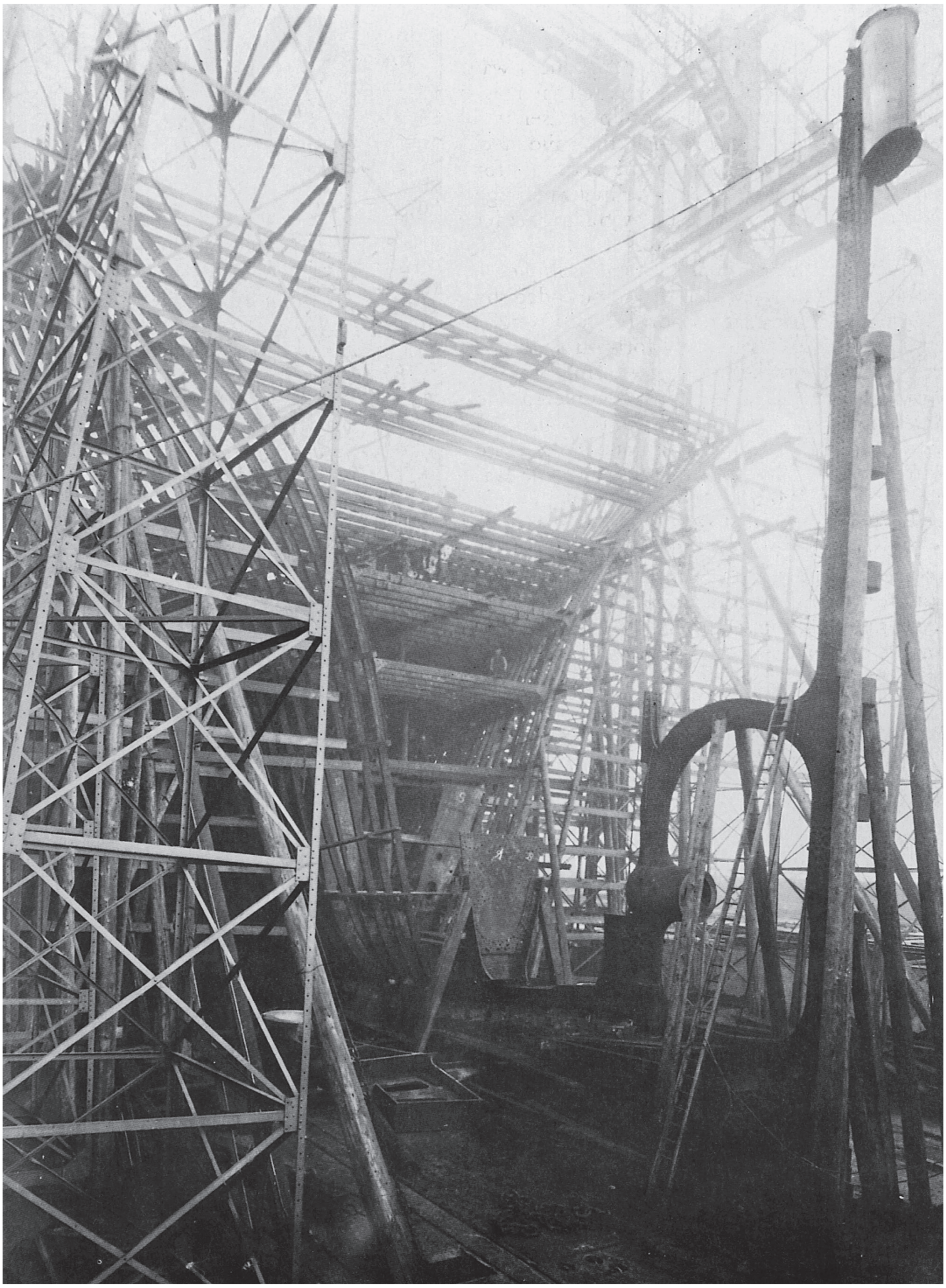


Fig. 5-12 **Upper Stern Frame of *Titanic* in Position** – The scarfs have been temporarily bolted through until the riveters can complete their work, while large timbers and guy wires steady the stern post until the remaining frames and shell plating can complete the stern frame's attachment to the fabric of the hull. *(H&W/Authors' collection)*

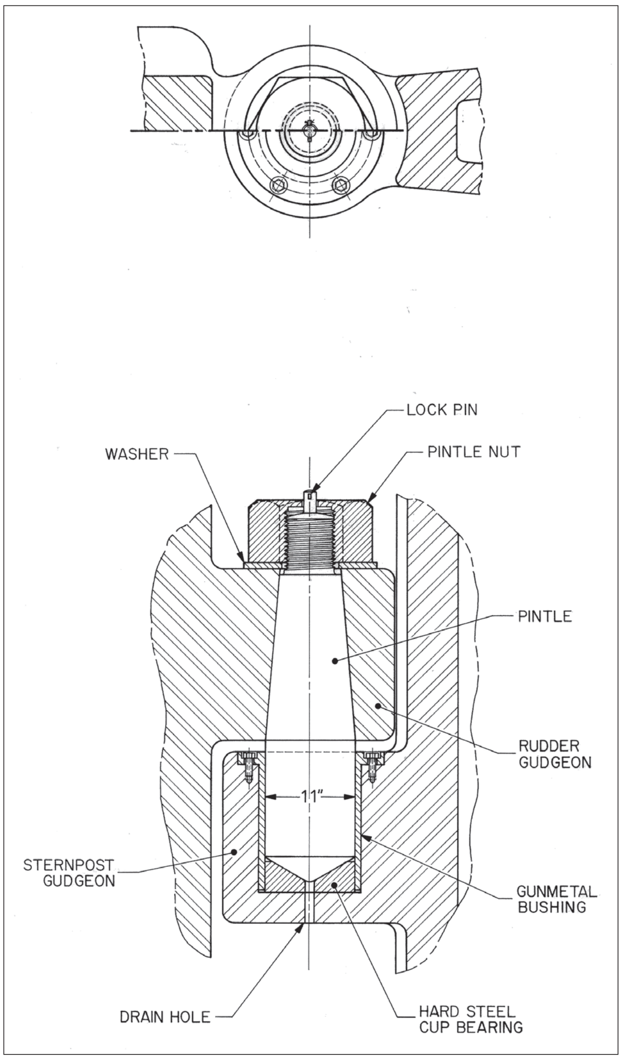


Fig. 5-13 ***Titanic*'s Rudder Gudgeons and Pintles.** *(Illustration by Scott Andrews)*

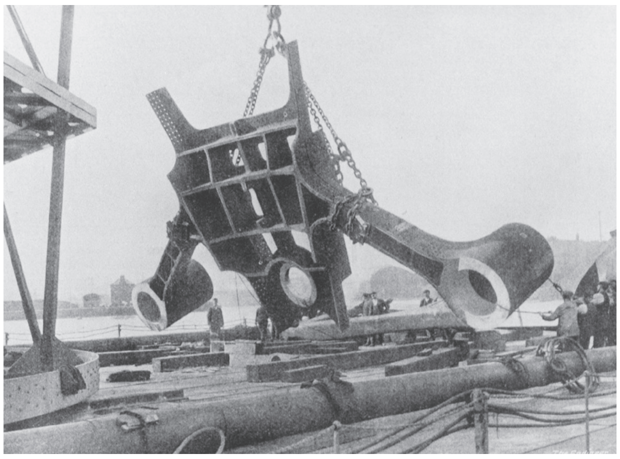


Fig. 5-14 **After Shaft Brackets of *Olympic* Being Unshipped** – The after shaft brackets of *Olympic* being off-loaded onto the slip from the deck of the floating crane. *(*The Engineer*/Authors' collection)*

Right Fig. 5-17 **After Shaft Brackets in Shop** – The after shaft brackets of *Titanic* in the shop before being taken to the construction slip. Here, the port and starboard halves have been temporarily assembled for machining of the attachments to the hull. *(*The Engineer*/Authors' collection)*

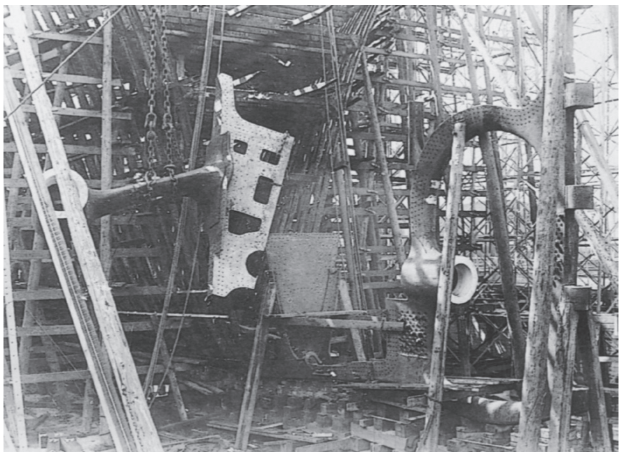


Fig. 5-15 **After Shaft Brackets of *Olympic* Being Put Into Position** – Once on the slip, the shipwrights disassembled and swung the two halves of this massive casting into place separately and then bolted them together permanently along the center flange after they had been properly positioned. *(*The Engineer*/Authors' collection)*

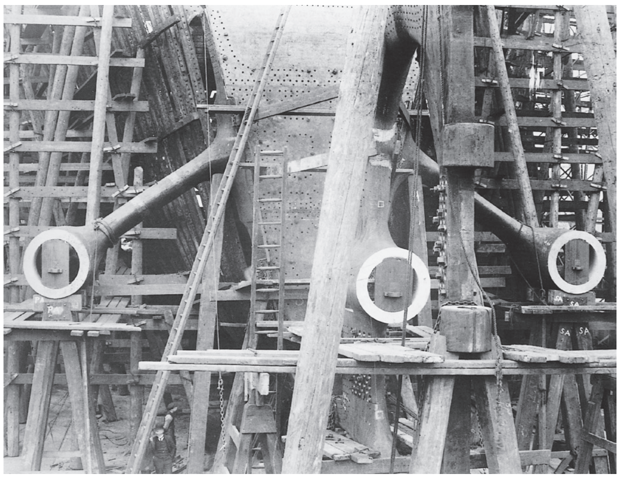
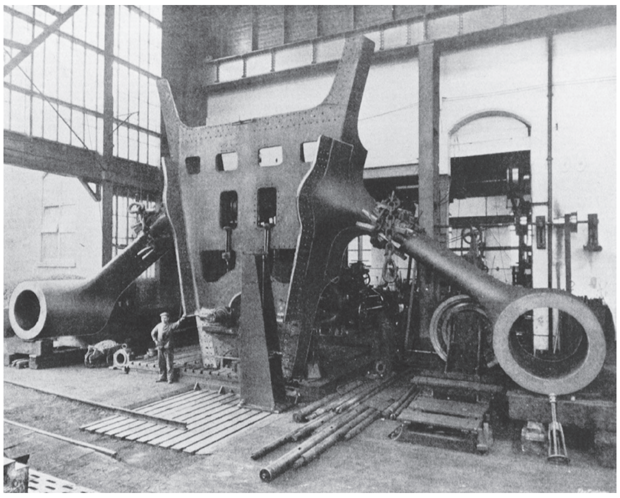


Fig. 5-16 **After Shaft Brackets in Position on *Olympic*** – Wooden boards inserted in the shaft openings had centered attachments for rigging a piano wire to aid the shipwrights in determining the centerline of the shafts along their passage through the ship. This was done to aid the positioning of holes through bulkheads, for locating the centerline of bearing stools, etc. *(H&W/Authors' collection)*



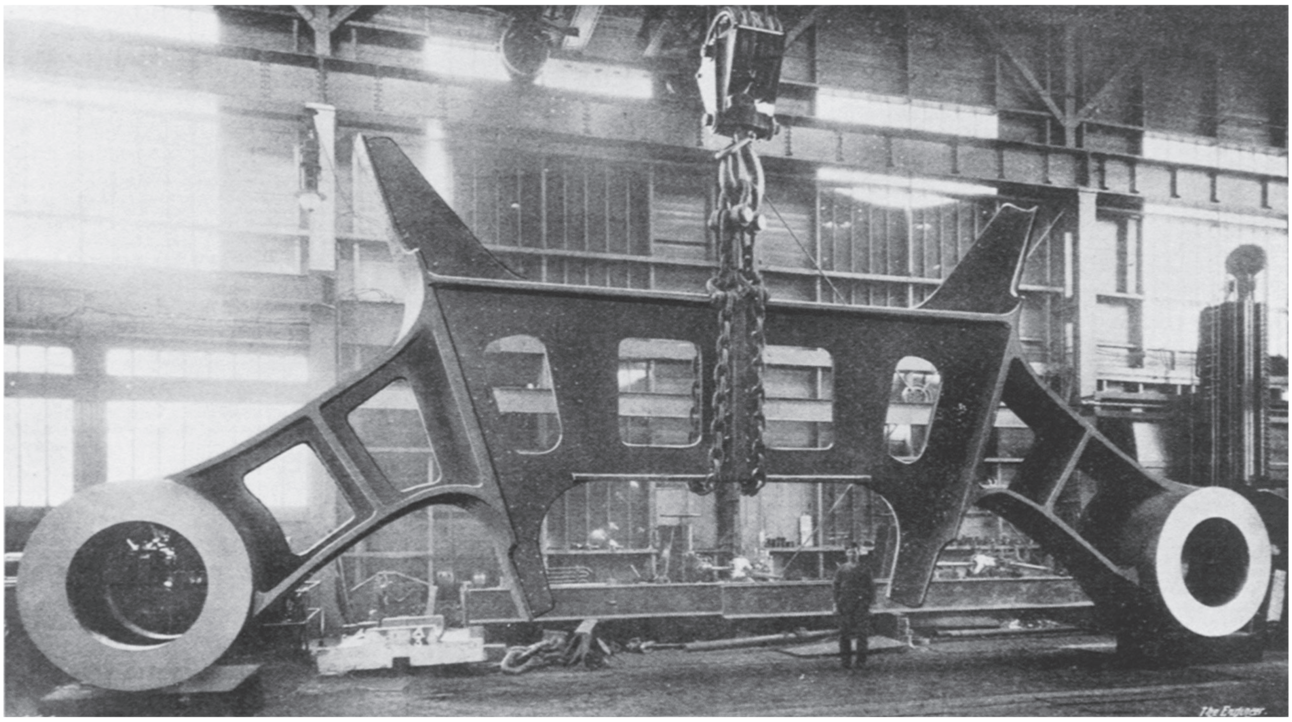


Fig. 5-18 **Forward Shaft Brackets** – The forward shaft brackets of *Titanic* assembled in the shop before being taken to the construction slip. *(*The Engineer*/Authors' collection)*

connection was provided by a series of intercostal plates running from 139A forward to 133A.

(4) By making certain that the stern frame was securely attached to the hull by means of the shell plating, to which it was riveted by three to five rows of rivets. These rivets were spaced a maximum of five diameters apart and were about ¼in larger in diameter than what was required according to the thickness of the plates, which were as thick as the garboard strakes. They did not need to exceed 1¼in in diameter, as it was practically impossible to obtain good hand riveting with larger rivets. While the shell plating was reduced in thickness from the half-middle length to the ends, the plates which took the stern frame were made approximately equal to the thickness of the garboard strakes, especially around the propeller bosses and posts. Finally, in a manner similar to what was done with the forefoot casting, the keel plate was dished around the forward end of the stern frame casting, overlapping it a distance of approximately 5ft 6in.

Rudder

The rudder is that part of the vessel which controls the direction of her movements when afloat and in motion. In its simplest form, a rudder consists of a wide, flat

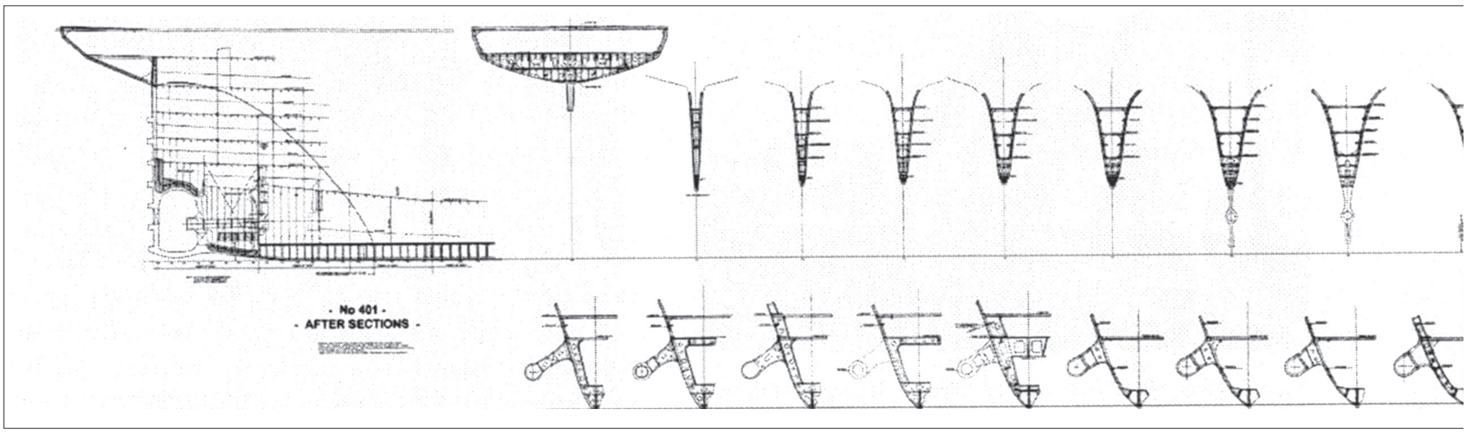


Fig. 5-19 **After Sections Drawing** – The after sections of an *Olympic*-class liner. This particular drawing was for *Britannic*, but little, if any, difference would be apparent with *Olympic* and *Titanic* except the slightly wider spread of the outboard propeller shafts on *Britannic*.

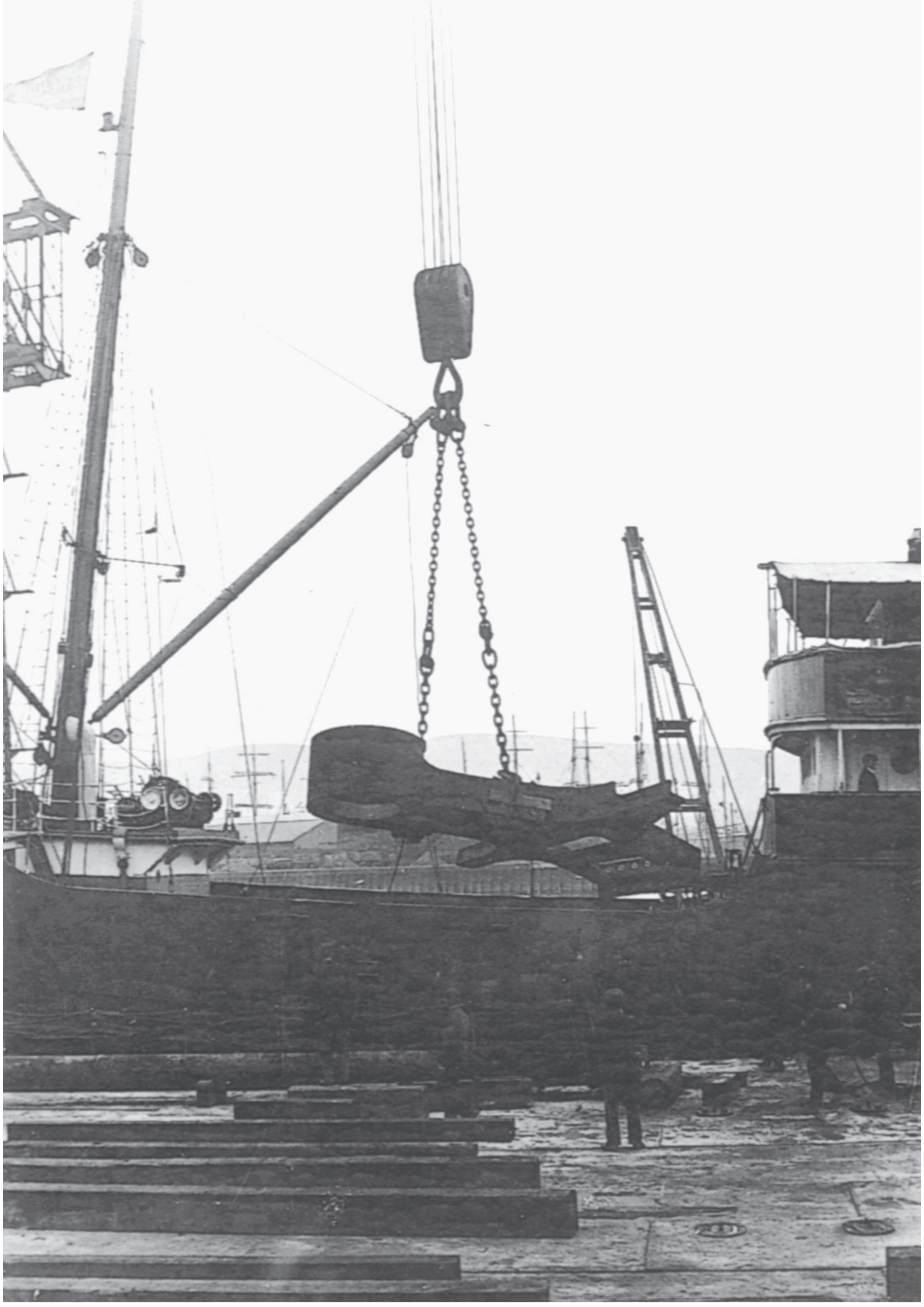
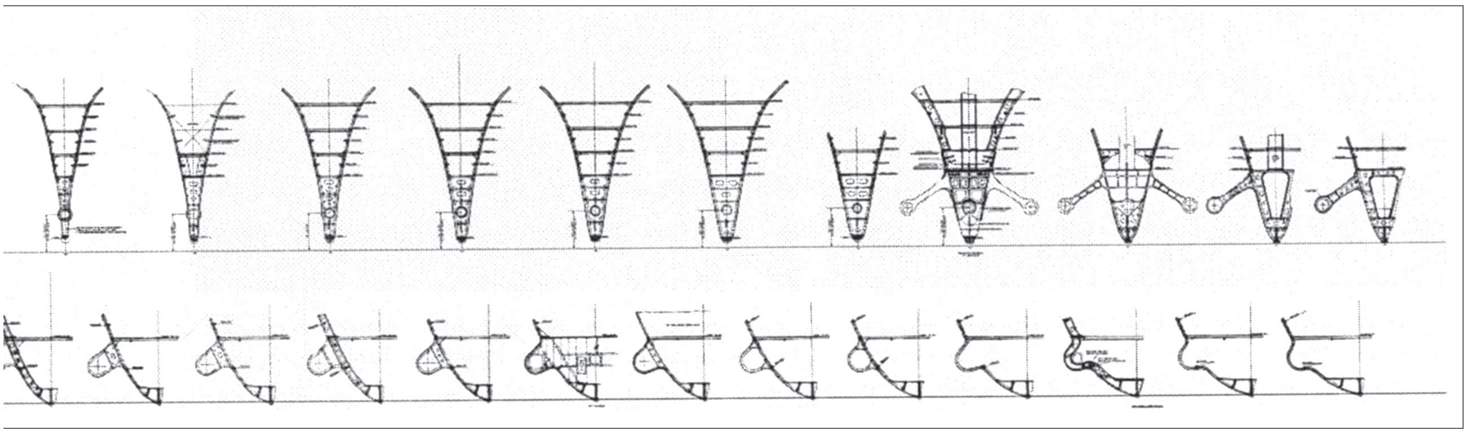


Fig. 5-20 **Forward Shaft Brackets Being Unshipped** – The forward shaft brackets of the *Olympic* being hoisted onto the construction slip. *(H&W/ Authors' collection)*



This drawing shows the aft end of the ship dissected frame by frame. The plating visible in the section seen at Frame 148A was the transom frame to which the head of the stern post was riveted. *(Illustration by Bruce Beveridge based on original H&W No.433 After Sections drawing)*

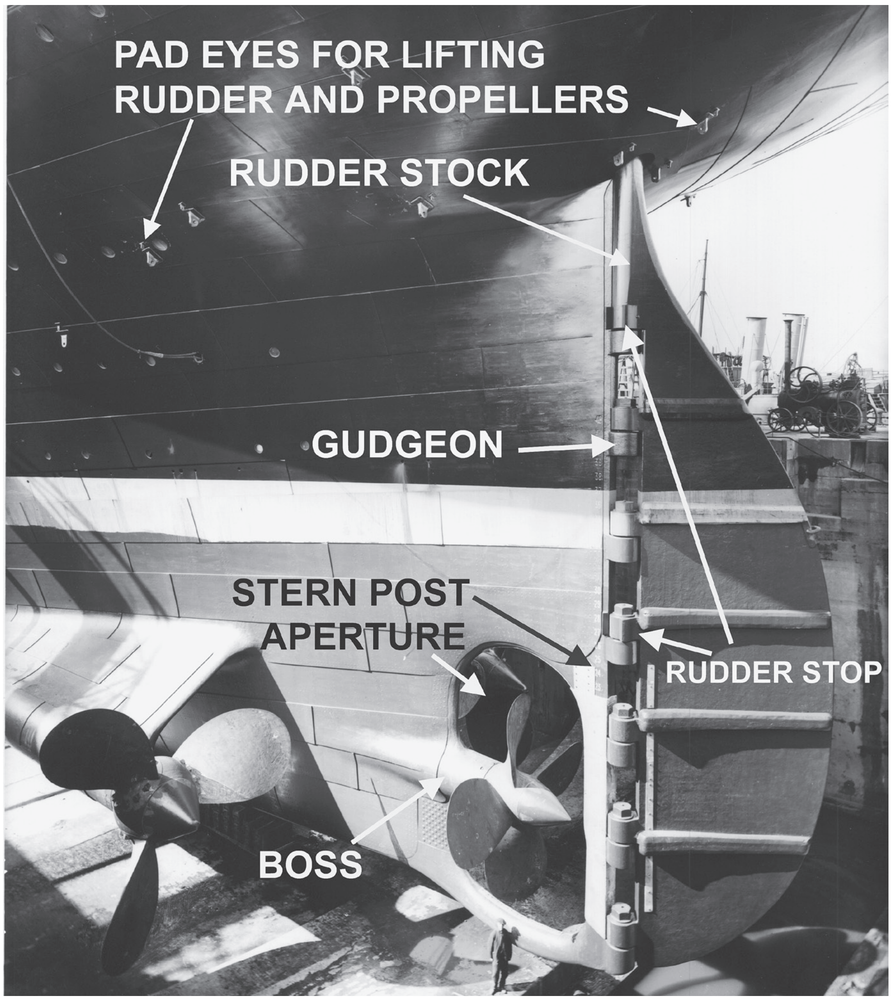


Fig. 5-21 **Stern Frame and Rudder on *Olympic*** – The main parts of the stern frame and corresponding rudder fittings. *(H&W/Authors' collection)*

blade and a vertical shaft or stock by which this blade is turned so as to steer the ship.

Rudders are either of the 'semi-balanced' or 'unbalanced' type. A semi-balanced rudder has part of the blade extended forward of the rudder stock, while an unbalanced rudder has all of its effective area aft of the stock. A semi-balanced rudder requires a smaller steering engine than an unbalanced rudder, as the water pressure on the forward edge tends to partially counterbalance the forces acting against the after edge. About 25 per cent of the total area of the rudder is placed in the forward balancing section. Semi-balanced rudders were generally used on warships as they give maximum maneuvering ability without requiring excessively powerful steering gear. Quite often the term 'balanced rudder' is used instead of 'semi-balanced rudder'. The term 'semi-balanced' is used in this text as no rudder is truly balanced throughout the entire turning angle. The unbalanced rudder was used in many ocean liners of the time. In the case of the *Olympic*-class ships, the design of the stern and the arrangement of the propellers necessitated the adoption of this type of rudder.

Titanic's rudder was hinged about an axis at its forward end. It was supported and secured by means of nickel-steel pintles which fit into the gudgeons on the stern post of the stern frame. In order to keep the rudder from turning side to side at an angle beyond 40° from the centerline, a double rudder stop was cast into the stern post at the fourth gudgeon from the bottom and at the top gudgeon. A corresponding stop was cast onto the pintle at the same location on the rudder.

Titanic's rudder was also fabricated by the Darlington Forge Company. The rudder was made in six pieces; the five sections which comprised the blade were mild steel castings. The rudder stock was of forged steel, 23½in in diameter, and was made from a special ingot of the same quality as used for gun jackets.[1] On the completion of the forging, an inspection hole was bored through the stock of the rudder in order to ensure that there were no flaws.

The sections were coupled together by strong bolt-flanges and secured by about 160 turned and fitted forged bolts varying from 2 to 3½in in diameter. These bolts were inserted from the top so that, in the event of the nut coming off, the bolt remained in place. Following their installation, the bolt heads and nuts were buried in

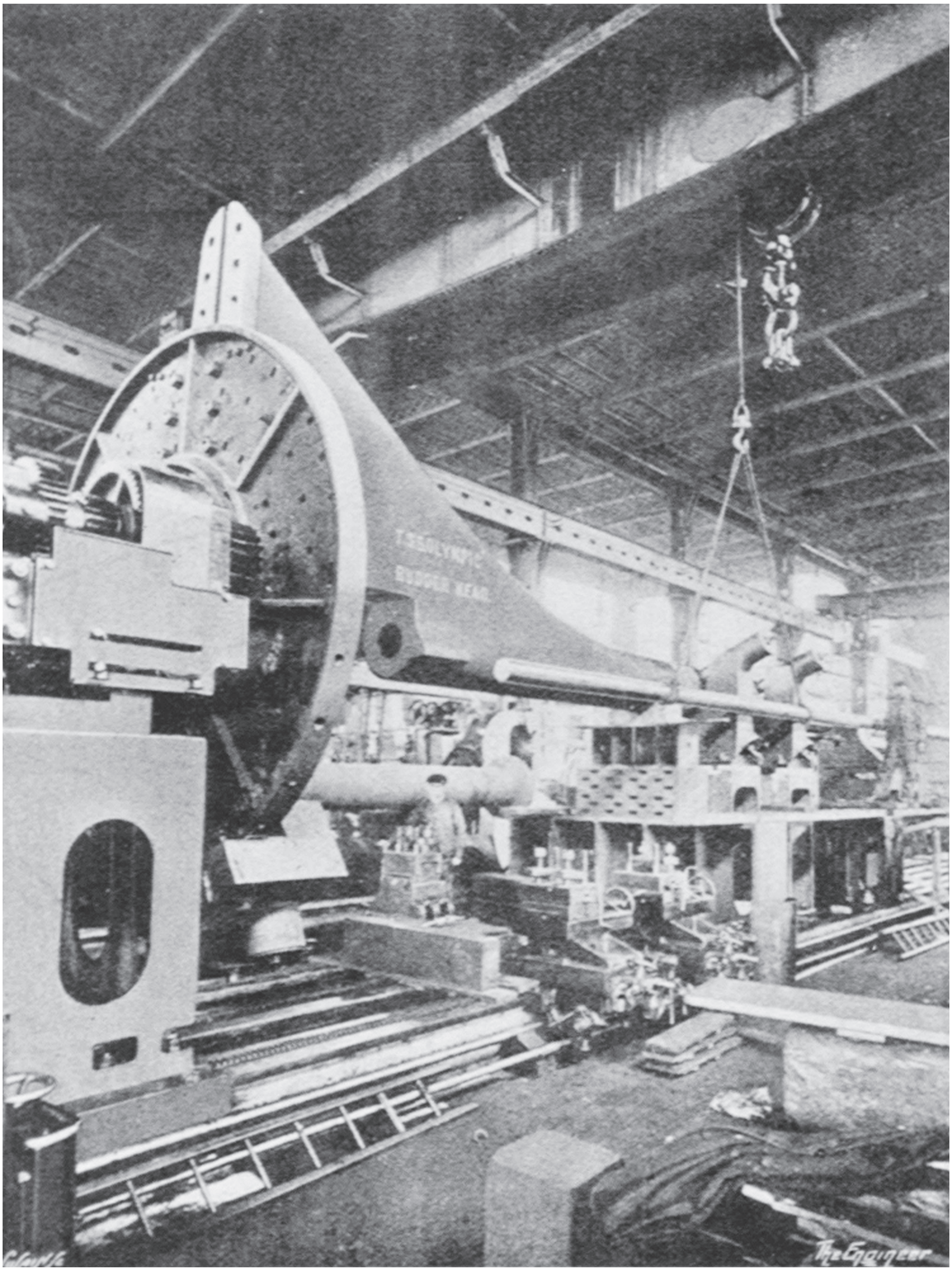

T.S.S. OLYMPIC
RUDDER HEAD
The Engineer

Fig. 5-22 **Rudder Head of *Olympic* in the Lathe**. *(*The Engineer*/Authors' collection)*

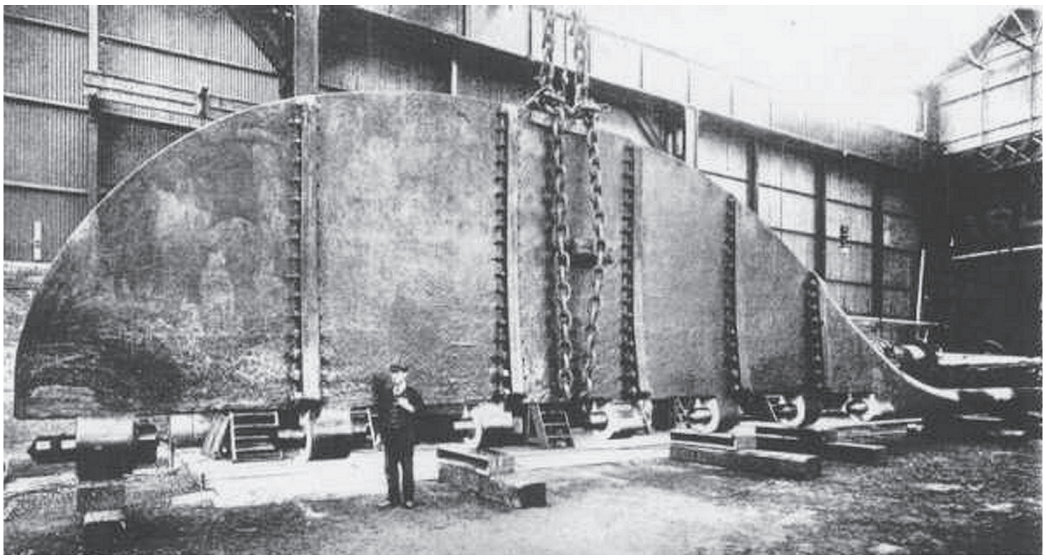
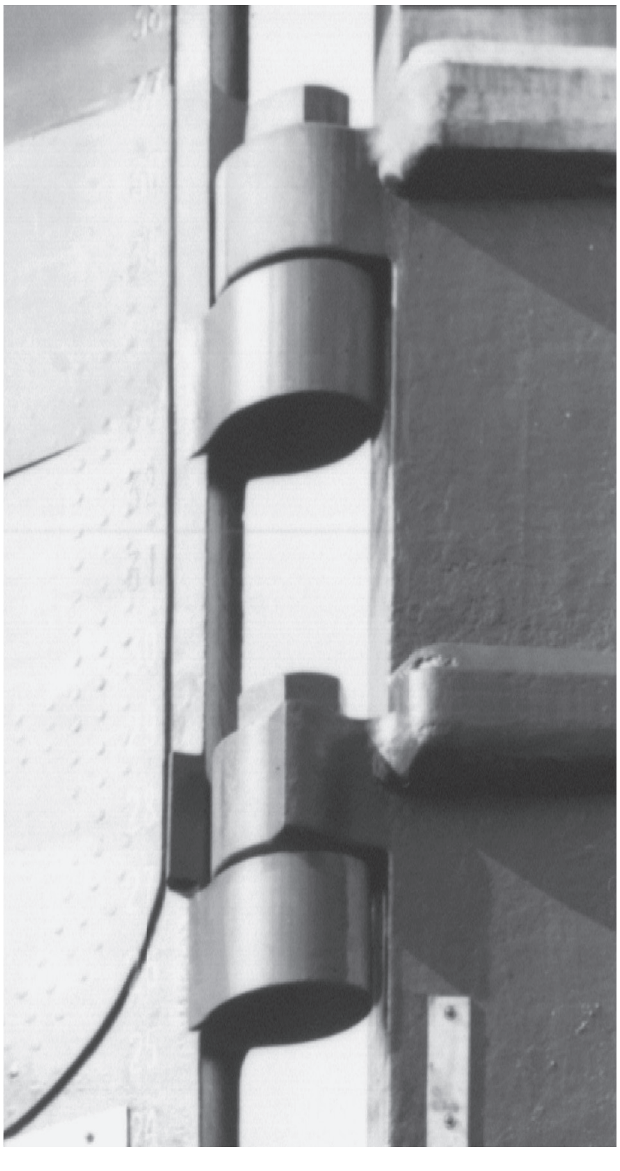
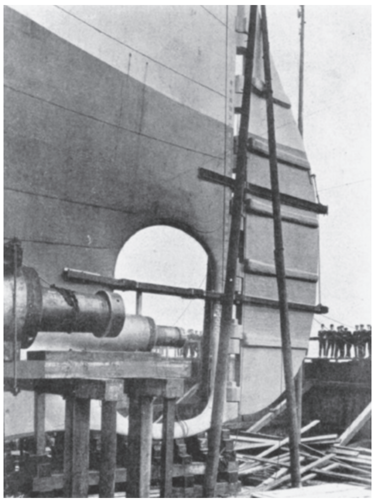


Fig. 5-23 **Assembled Rudder in Shop** – The assembled rudder prior to being fitted to *Olympic*. Visible in this view are the flanges through which the individual sections were bolted together. The bolt heads and nuts would then be buried in a 'fairing compound' of Portland cement when finished. This gave the appearance of wide, smooth horizontal ribs on each side of the rudder. The rudder pintles, with their conically pointed ends, can be seen projecting from the bottoms of the rudder gudgeons. Also visible are the solid nuts which retained each pintle. *(*Engineering*/Authors' collection)*





Above Fig. 5-25 ***Olympic*'s Rudder Prior to Launch** – The rudder and stern frame of *Olympic* as it appeared immediately prior to launch. The horizontal beams running from the trialing edge of the rudder and onto the hull just below the load waterline were bolted and chained in place to keep the rudder from moving while the hull backed into the water. *(*The Engineer*/Authors' collection)*

Left Fig. 5-24 **Gudgeon and Rudder Stopper** – An enlargement showing two of *Olympic*'s stern post and rudder gudgeons. The upper set is plain, while the lower set includes one of two 'rudder stoppers' incorporated in the castings; a second rudder stopper was built into the very top gudgeon at the base of the rudder stock. *(H&W/Authors' collection)*

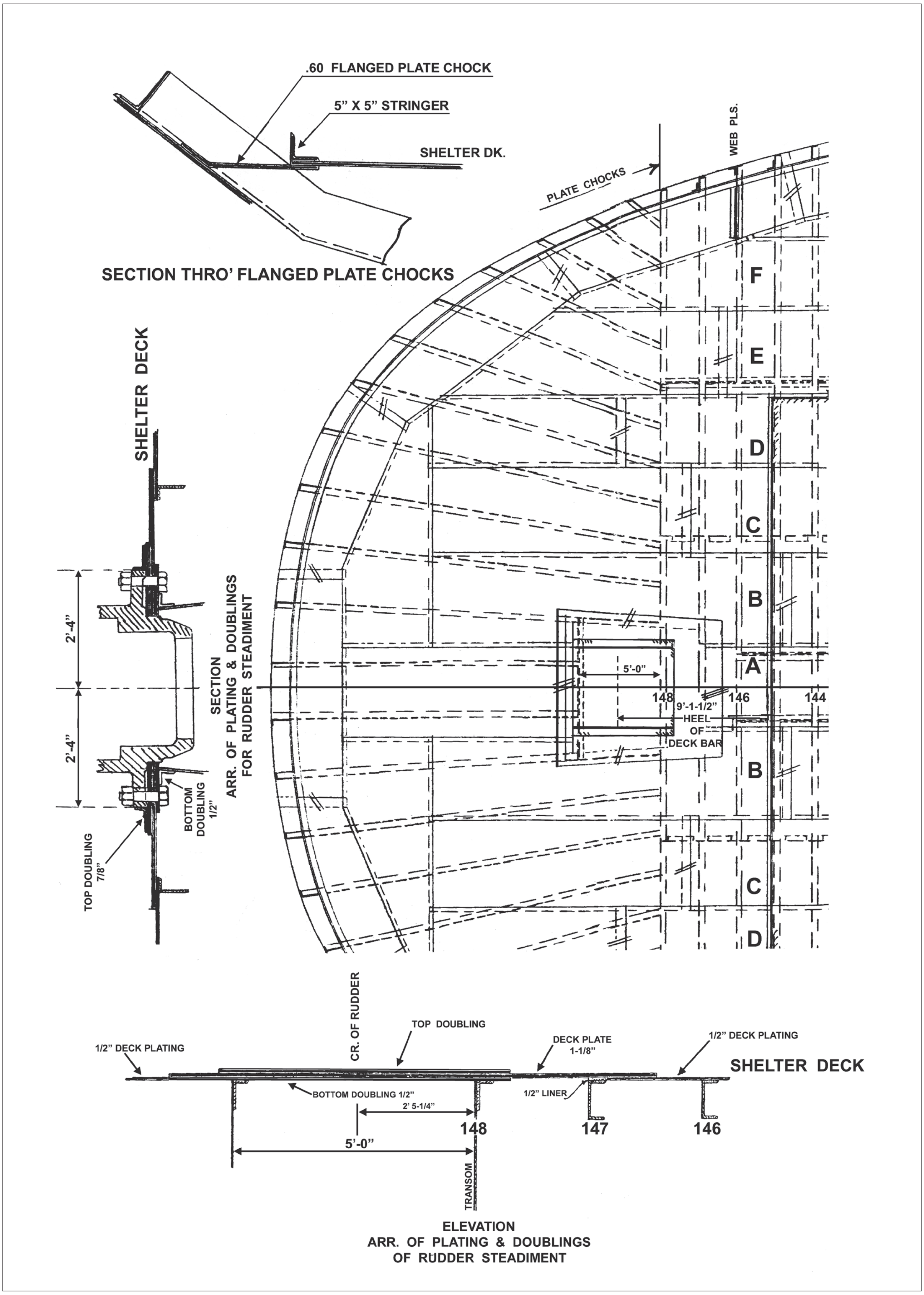

.60 FLANGED PLATE CHOCK
5" X 5" STRINGER
SHELTER DK.
SECTION THRO' FLANGED PLATE CHOCKS
PLATE CHOCKS
WEB PLS.
F
E
D
C
B
A
B
C
D
SHELTER DECK
2'-4"
2'-4"
SECTION
ARR. OF PLATING & DOUBLINGS
FOR RUDDER STEADIMENT
BOTTOM DOUBLING 1/2"
TOP DOUBLING 7/8"
5'-0"
148
146
144
9'-1-1/2"
HEEL OF DECK BAR
CR. OF RUDDER
TOP DOUBLING
1/2" DECK PLATING
DECK PLATE 1-1/8"
1/2" DECK PLATING
SHELTER DECK
BOTTOM DOUBLING 1/2"
1/2" LINER
2' 5-1/4"
148
147
146
5'-0"
TRANSOM
ELEVATION
ARR. OF PLATING & DOUBLINGS
OF RUDDER STEADIMENT

Fig. 5-26 **C Deck Rudder Steadiment** – The aft end of the Shelter Deck (C) showing the plating and framing in way of the rudder steadiment. *(Illustration by Bruce Beveridge based on original H&W Shelter Deck Iron plan)*

a layer of Portland cement, which was then faired into the ribs of the adjoining sections of the rudder; this was done both to reduce turbulence around the submerged portion of the blade and to protect the fasteners from the corrosive effects of sea water.

The overall height of the rudder was 78ft 8in and the maximum blade width was 15ft 3in, with an overall weight of 101¼ tons. It was carried by seven special bearing pintles 11in in diameter, made of hardened steel and having conical ends. Each pintle was arranged to take its own proportion of the rudder weight, bearing upon the previously mentioned hard steel discs inside the sternpost gudgeons. The pintles were the 'fitted' type, having a tapered shank which was drawn tightly into a similarly tapered bore in the rudder gudgeons.

The pintles were retained in the rudder gudgeons with solid covered nuts having set pins to prevent the pintles from turning. Because of the bushings added to the stern post gudgeons in which the pintles pivoted, there was little or no side slack movement of the rudder. A special feature was that the bottom of the rudder was so arranged that screw jacks could be employed for lifting it in dry dock. To further aid removal, pad eyes were fitted beneath the counter in specific locations to allow the use of block and tackle to maneuver the rudder out of its usual position.

Notes

1. In early, large, built-up gun barrels, the jacket was the outer case of the barrel. By the late nineteenth century, in the type of guns employed in the main battery of ships such as battleships ('dreadnoughts'), the term 'jacket' referred to the rear portion of one of the inner layers which surrounded the breech and chamber. The material employed for this purpose had to possess exceptional strength in order to contain the terrific forces created within by the rapid expansion of the propellant charge.

Chapter 6

Watertight Bulkheads, Watertight Doors and Coal Bunkers

Watertight subdivision

The watertight subdivision of *Titanic* was considered very comprehensive at the time of her building. The design was such that that any two main compartments could be flooded with the ship loaded to the maximum load draft without affecting the safety of the ship. The minimum freeboard the vessel would have in the event of any two compartments being flooded was between 2ft 6in and 8ft from the deck adjoining the top of the watertight bulkheads (known as the 'bulkhead deck'). In *Titanic*, any three of the four forward compartments could have been flooded without sinking the ship to the top of her lowest watertight bulkheads. The ship would remain afloat even with the four forward compartments flooded in a relatively calm sea; however, in heavy seas the water would have been encouraged to run along the decks aft of the forward bulkheads, finding its way below into the fifth compartment aft through the various non-watertight openings within the decks. Even in this state, survival of the ship would still be possible, providing the rate of flooding was not beyond the capabilities of the bilge pumps. However, if in addition to the first four compartments, uncontrollable flooding of or damage to more compartments occurred, as was the case on the night of April 14–15, 1912, the eventual loss of the ship would be inevitable.

There were fifteen transverse watertight bulkheads dividing *Titanic* along her length into sixteen separate compartments. The Reciprocating Engine Room was the largest of these compartments, being 69ft long and nearly the maximum breadth of the hull at its forward end.

Commencing from forward, the watertight bulkheads were lettered 'A' through 'P' (exclusive of 'I'). (Note: from this point forward, when specific watertight bulkheads are referred to, the abbreviation 'WTB' will precede the letter designation.) The watertight integrity of these bulkheads was maintained up to either E or D Decks. WTB A extended structurally to C Deck, but was only watertight to D Deck. Although the transverse bulkheads were watertight, the bulkhead decks themselves were not, with the exception of the Orlop Deck abaft of the turbine engine room and forward of the collision bulkhead, both of which were watertight flats. In all instances, the tops of the watertight bulkheads were well above the load waterline and exceeded the regulations of the time. In this respect, the system of watertight subdivision employed in *Titanic* met and even exceeded many of the regulations which apply to passenger vessels being built at the time of this writing.

WTBs E, F, G, H and J within the boiler rooms did not have watertight doors physically within their structure at the stokehold level, as each of these bulkheads was located midway between the coal bunkers located at the forward and after ends of each boiler room. The watertight doors permitting access through these bulkheads were located at the end of a watertight passage extending aft a distance of between 9ft and 13ft 6in, leading from the watertight bulkhead proper through the coal bunker into the next compartment.

The foremost watertight bulkhead was termed the 'collision bulkhead'. It was fitted for the specific purpose of serving as an inner skin in the event the bow should be broken open in an end-on collision. Because of the relatively small volume of the peak compartment, the amount of water that could enter would have little effect on the vessel's trim; in addition, due to the small area of this bulkhead, the bursting pressure it could be subjected to was small and, being narrow, it was naturally strong. However, the integrity of the bulkhead depended directly on the amount of damage sustained by the bow. To ensure the bulkhead's efficiency, it was placed a distance from the stem about one twentieth of the vessel's length.

The Merchant Shipping Act of 1854 required that screw steamers have a bulkhead near the stern. Called the 'after peak' bulkhead, its purpose was to prevent the inrush of water which might result from the fracture of a tail or propeller shaft. The watertightness of the hull where a tail shaft passed through the stern was secured by a watertight gland, or 'stuffing box'. This could not be placed directly at the sternpost as there was usually insufficient space there owing to the fineness of the hull. In order that the stuffing box could be easily accessible, and to provide a rigid bearing for the tail shaft, a tube of cast iron forming a journal was introduced, the after end of which was fixed to the stern post or boss arm and the forward end to the after peak bulkhead. The sea could enter the tube around the shaft but was kept back by the stuffing box placed at its forward end. The entire tube was thus enclosed in a watertight compartment (the after peak) so that if the tail shaft or tube fractured, the incoming water could be confined. It was possible that the damage might be so widespread as to involve the entire tube including the watertight stuffing box and peak bulkhead supporting it; to provide for this, the entire after portion of the shafts were enclosed in a watertight compartment known as the 'shaft tunnel' or 'shaft alley'. The after end of the shaft tunnel abutted the peak bulkhead, while the forward end terminated at WTB N, which divided the tunnel from the Electric Engine Room. An intermediate bulkhead – WTB O – was introduced at frame 111A in the middle of the space between the Electric Engine Room and the after peak bulkhead. In addition to the stuffing box at the after peak bulkhead, in order to maintain watertight integrity of the machinery spaces in the event of a compartmental breech, there was a watertight gland fitted around each shaft at every watertight bulkhead through which they passed.

Bulkhead construction

The watertight bulkheads added to the transverse strength of the hull and were connected to the shell plating by means of double angle bars called 'bulkhead bars' or 'boundary bars', between which the bulkhead plating was fitted. These angles were generally of the same size as the frames. The connection to the Tank Top was also made by means of double angles, in this instance called 'foundation bars'. As the watertightness had to be maintained from lower to upper extremity, a connection to each of the steel decks was made by means of double angle bars, called 'deck bars' or 'deck angles', which were of similar size to the reverse frames.

From the level of the Lower Deck (G) down, the bulkheads were built up from horizontal strakes of joggled 'in-and-out' steel plates. The ends of the horizontal strakes, rather than being carried directly to the sides of the hull, were lapped at each end onto a vertically oriented margin plate, the outboard edge of which was sandwiched between the double angles connecting the bulkhead to the shell. In the 'tween deck spaces above the Lower Deck (G), the bulkheads were built up from vertical plates which were generally between 5 and 6ft in width and approximately the distance between the decks in height. The end joints were lapped and, in order to eliminate the need for tapered packing pieces

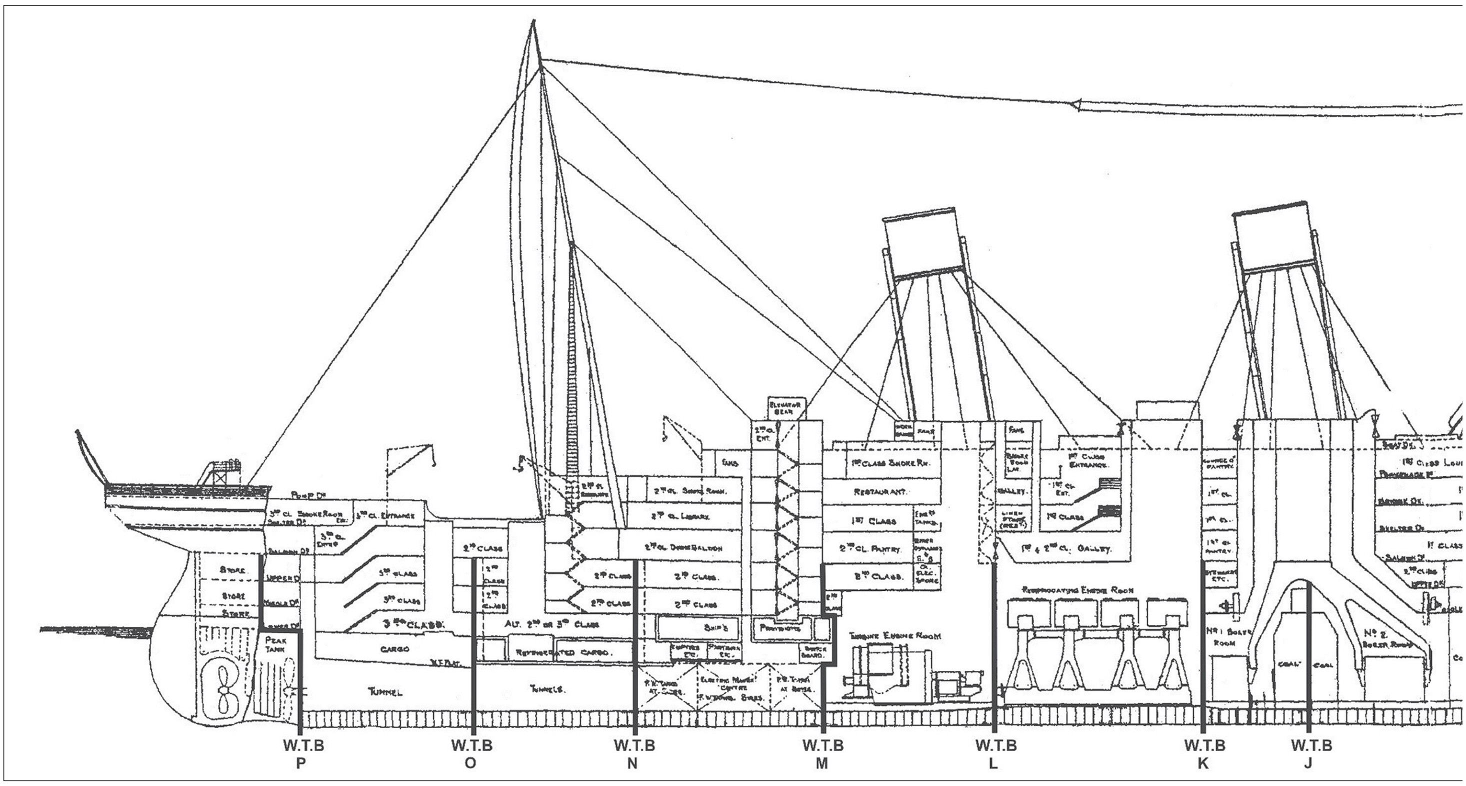


Fig. 6-1 **Watertight Bulkheads** – Starboard Inboard Profile – Illustration showing the location and height of the fifteen transverse watertight bulkheads, indicated by the dark lines. *(Illustration by Bruce Beveridge)*

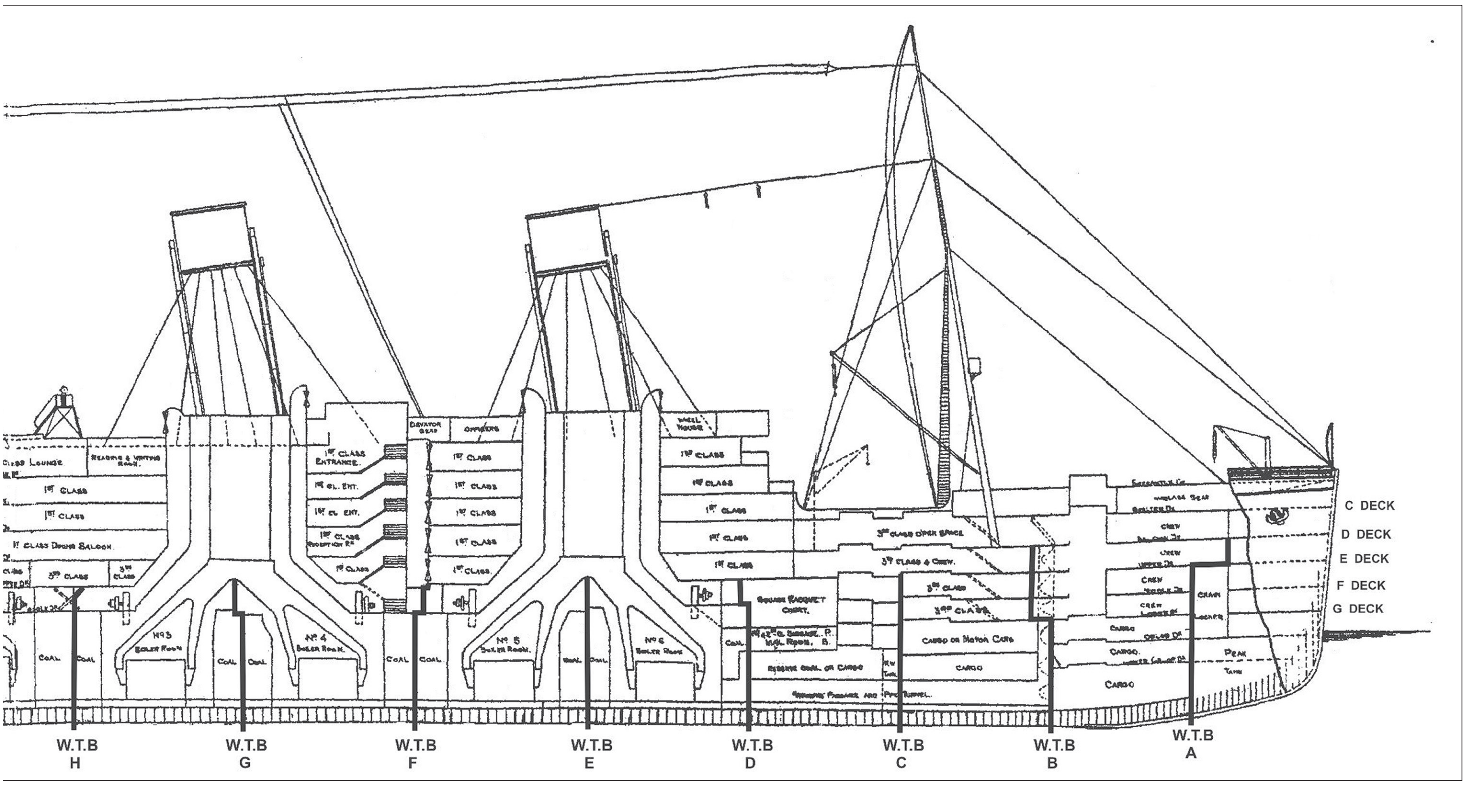
where they overlapped at the landings and in way of the deck angles, the corners were machine-tapered.

Because the pressure of water upon a bulkhead in a flooded compartment would be greater on the lower half than the upper, it was the practice to gradually increase the thickness of each successive strake of plating from top to bottom. As an example, the vertical plates of *Titanic*'s WTB D forward of No.6 Boiler Room were .30in thick between F and E Decks and .34in thick between G and F Decks, while below G Deck, the horizontal strakes from top to bottom were successively .40in, .46in, .50in, and .56in thick.

While the overlapping of the edges and butts of the plates gave a degree of stiffness to the area of plating, it was far from adequate to provide the strength required to withstand the pressure to which a bulkhead might be subjected from a head of water in the event of a hold or machinery space becoming flooded. To provide this additional strength, each bulkhead was reinforced with a well-designed arrangement of stiffeners, braces and brackets. The majority of the watertight bulkheads on *Titanic* were reinforced with a combination of bulb angle, channel bar and I-bar stiffeners. Where additional strength was required, or where these stiffeners were required to provide support for the ends of deck girders and other overhead structures, double channels or built-up webs, having double angle face and bulkhead bars, were introduced.

Special consideration was given to the stiffening of WTBs K and L, respectively the forward and after bulkheads of the Reciprocating Engine Room, as this was the largest watertight compartment as well as the tallest open space within the hull. Between the Tank Top and G Deck, WTB L was reinforced on the after side by 24in-deep built-up web stiffeners, curved at the top and reduced to 18in, switching to I-bars and then channel bars at the very ends beneath the discharge recesses. Between G and E Decks, channel bar stiffeners were employed within the Turbine Engine Room casing, while bulb angles were used outboard of the casing at these levels, and throughout the width of the bulkhead between E and D Decks. On the forward side, three deep webs were fitted. Two web stiffeners 36in-deep were located port and starboard 29ft outboard of the centerline, running from the Tank Top to the underside of G Deck and the sides of the reciprocating engine casing. The web on the centerline was 6ft deep and ran intercostally from the Tank Top to the underside of D Deck, being interrupted by the steel deck platform running athwartships across the reciprocating engine casing at G Deck.

For WTB K, reinforcement between the Tank Top and G Deck was provided by 24in-deep built-up web stiffeners fitted to the forward side. The majority of these webs were curved at both ends, reduced to 12in-deep at the bottom and 8in-deep at the top, and were


Reading & Writing Room.
1st Class
1st Class
1st Class Dining Saloon
3rd Class
1st Class Entrance.
1st Cl. Ent.
1st Cl. Ent.
1st Class Reception Rm
1st Class
Elevator Gear
Officers
Wheel House
3rd Class Open Space
3rd Class & Crew.
3rd Class
3rd Class
Squash Racquet Court.
Cargo or Motor Cars
Reserve Coal or Cargo
Cargo
Cargo
Cargo
Peak Tank
Crew
Crew
Crew
Crew
No 3 Boiler Room
No 4 Boiler Room.
No 5 Boiler Room.
No 6 Boiler Room
Coal
Coal
Coal
Coal
Coal
Coal
Coal
Coal
Coal
C DECK
D DECK
E DECK
F DECK
G DECK
W.T.B H
W.T.B G
W.T.B F
W.T.B E
W.T.B D
W.T.B C
W.T.B B
W.T.B A

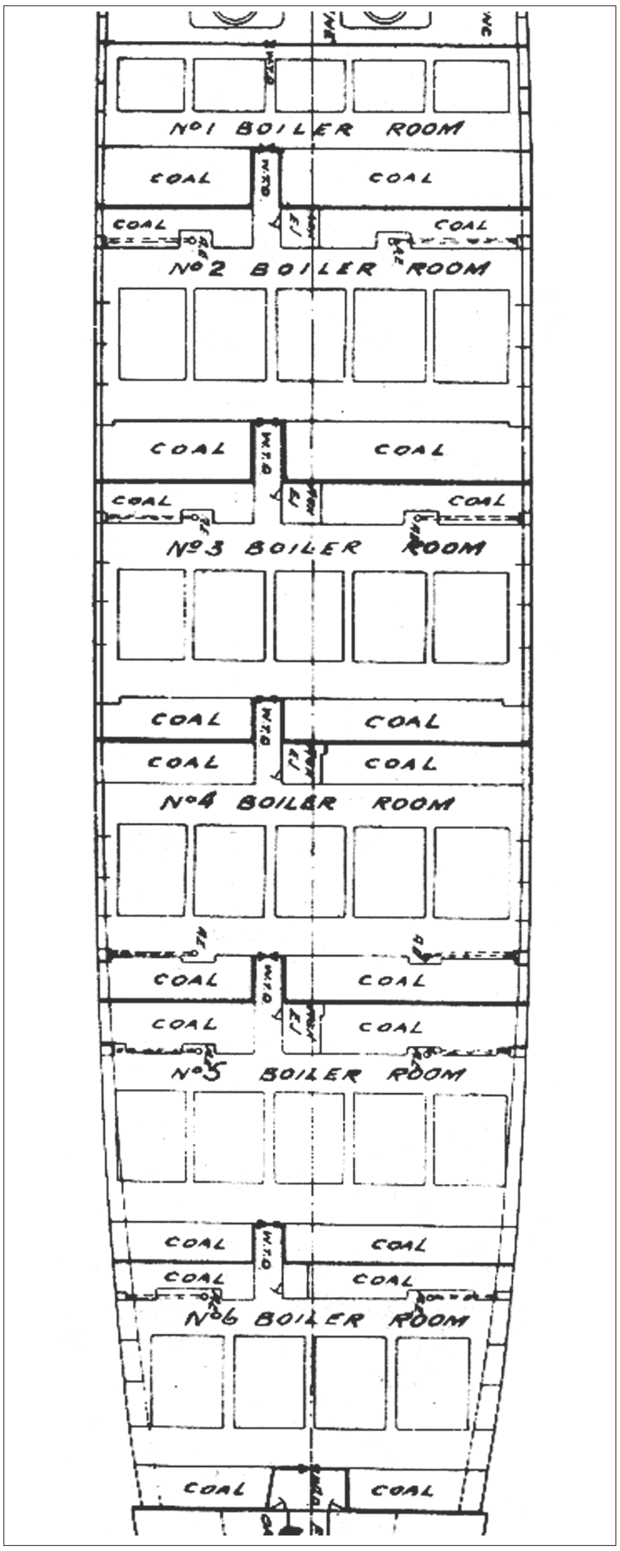

Nº1 BOILER ROOM
COAL
COAL
W.T.D.
COAL
COAL
Nº2 BOILER ROOM
COAL
COAL
W.T.D.
COAL
COAL
Nº3 BOILER ROOM
COAL
COAL
W.T.D.
COAL
COAL
Nº4 BOILER ROOM
COAL
COAL
W.T.D.
COAL
COAL
Nº5 BOILER ROOM
COAL
COAL
W.T.D.
COAL
COAL
Nº6 BOILER ROOM
COAL
COAL

Fig. 6-2 **Watertight Bulkheads in Way of the Boiler Rooms** – Here, the watertight bulkheads are indicated by the dark lines, as are the passages through the coal bunkers and the vestibule ahead of No.6 Boiler Room. (The Shipbuilder/*Authors' collection)*

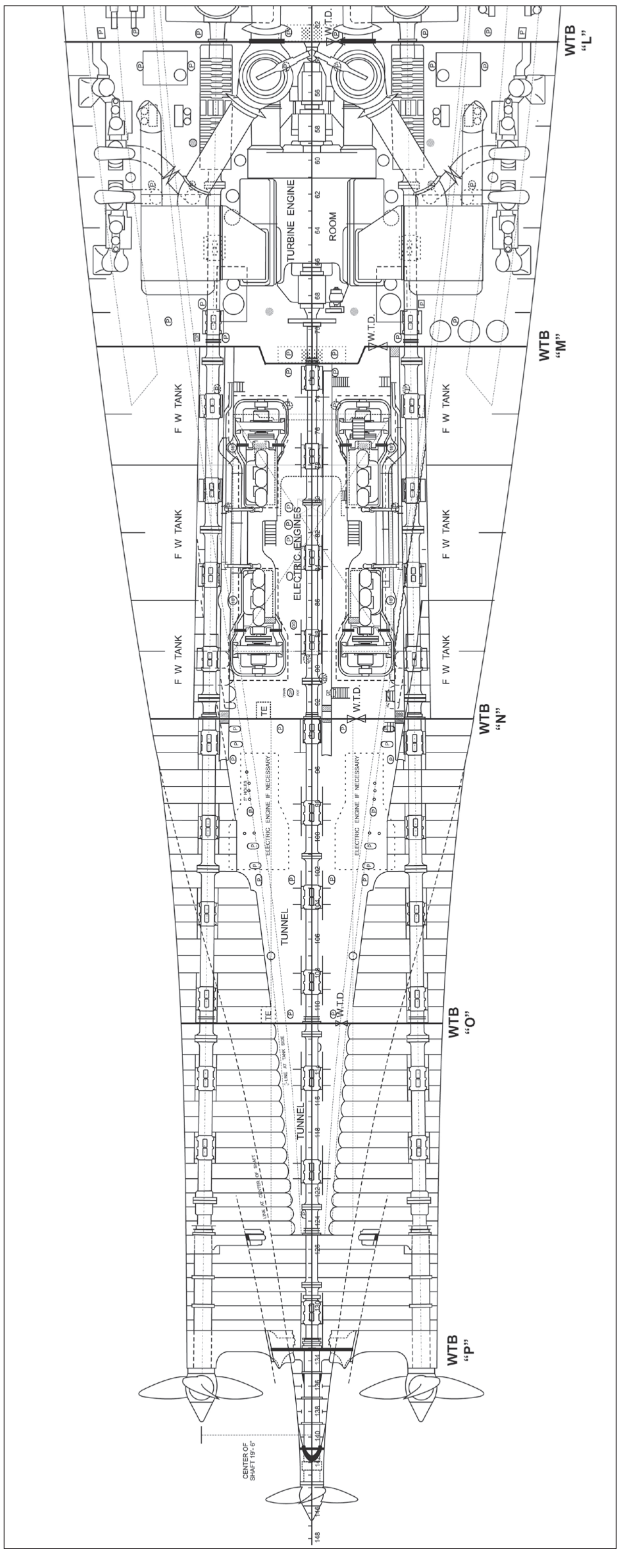

WTB "L"
W.T.D.
TURBINE ENGINE ROOM
W.T.D.
WTB "M"
F W TANK
F W TANK
F W TANK
F W TANK
F W TANK
F W TANK
ELECTRIC ENGINES
W.T.D.
WTB "N"
TUNNEL
W.T.D.
WTB "O"
TUNNEL
WTB "P"
CENTER OF SHAFT

Fig. 6-3 **Watertight Bulkheads in Way of Propeller Shafting** – This Illustration shows the watertight bulkheads through which the propeller shafts passed. A watertight gland, or 'stuffing box', was fitted around each shaft at the point it passed through the bulkhead. *(Illustration by Bruce Beveridge)*

tied to the deck plates at both ends through heavy knee brackets. Four straight 24in-deep built-up web stiffeners were interspersed amongst the curved ones. One of these was located on the centerline and another was located immediately to starboard of the watertight door between No.1 Boiler Room and the Reciprocating Engine Room, while the remaining two were situated beneath the short longitudinal bulkheads separating the 'tween deck coal bunkers from the steam pipe and bulkhead valve space at the G Deck level within the

No.1 Boiler Room. As with WTB L, I-bars and then channel bars were employed for the last few stiffeners at the very ends. Between G and F Decks, channel bar stiffeners were employed, located on the forward side throughout the width of the bulkhead. At F Deck and above, the stiffeners were relocated to the after side of the bulkhead; here, bulb angle stiffeners were employed.

The stiffeners for WTB A, the collision bulkhead, were of bulb angle between E and D Decks, while extra-thick channel bars of 6in- and then 12in-deep were used within the chain locker and Fore Peak Tank, respectively. The stiffening of the after peak bulkhead of *Titanic* presented a special case. Normally, bulb angle was employed for this purpose in most ship construction; however, the inboard webs of the after shaft brackets at frame 133A, which delineated the boundary of the After Peak Tank, were used as the framework to which the plates of WTB P were riveted below the Lower Deck (G) level. Above this level, WTB P was shifted, or 'stepped', aft to frame 139A, at which point it was continued upward through the intervening decks to the underside of the Saloon Deck (D); this portion of the bulkhead was stiffened with bulb angles in the normal fashion. The need to adequately stiffen and reinforce the bulkheads bounding the peak tanks was of special importance when considering that these were the only bulkheads which would be regularly subjected to a head of water, as they were generally kept completely filled while the vessel was underway. Though the stress upon these bulkheads when the peak tanks were filled was high, it was when through neglect or carelessness, a ship was allowed to proceed to sea with these tanks only partially filled, that serious damage to the peak bulkheads could occur from the hammering effect of so much water moving about freely within a confined space.

The usual form of rivets adopted in bulkheads which were not exposed to view, and where appearance was of no consequence, were the pan- and plug-head rivets with flush, beaten points, these being the most effective rivets for completely filling up the rivet holes and obtaining watertight results. However, where the bulkheads were exposed to view on one or both sides as in the engine rooms, it was more common to adopt pan-head rivets and to form a snap head on the other side, the snap head being on the exposed side of the bulkhead.

Both the lap and butt edges of the bulkhead plating from the bulkhead decks down to just below the level of the Lower Deck (G) were generally single-riveted, while from this point down to the Tank Top, double riveting was generally employed. Various pitches were employed depending upon the size and location of the rivets, the types of rivet heads and points specified, and the amount of strain the riveted seams were expected to deal with, both in the normal working of the ship and that which might be experienced *in extremis*, should a breach of the compartments bounded by the bulkhead occur. The diameter of the rivets, the pitch at which they were installed, and the style of the head and point used varied throughout the height of the bulkhead in accordance with both the scantlings of the materials connected and the expected stresses the individual seams and stiffening components might be subjected to. In order to properly record and identify the variety of rivets to be used within the construction of a given bulkhead, a table accompanied the set of views for that particular bulkhead, or for several bulkheads which might share the same design specifications. Below is such a table, for WTBs D and E, transcribed from the Harland & Wolff drawing titled 'Fore Body Bulkheads No.400-1', which contains the structural details of WTBs A through E:

Riveting – Watertight Bulkheads D and E

Description	Diameter	Pitch	Head	Point
To Tank Top Vertical Flange	⅜in	4⅜ Dia.	Pan	Flush
To Tank Top Horizontal Flange	–	–	Pan	Flush
Lower Deck Angle Vertical Flange	¾in	3¾ Dia.	Pan	Flush
Lower Deck Angle Horizontal Flange	–	–	Pan	Flush
Middle Deck Angle Vertical Flange	¾in	3¾ Dia.	Pan Below Deck; Flush Above	Flush
Middle Deck Angle Horizontal Flange	–	–	Pan	Flush
Angles Under Upper Deck – Vertical Flange	¾in	3¾ Dia.	Flush	Flush
Angles Under Upper Deck – Horizontal Flange	–	–	Pan	Flush
5¼in Landings & 6in Butt Laps Double	⅜in	4 Dia.	Pan	Flush
4½in Landings, 5in & 7½in Butt Laps	¾in	3½ Dia.	Pan	Flush
'Tween Deck Vertical Laps	¾in	3½ Dia.	Pan	Flush
4in x 4in Web Angles To Bulkhead	⅜in	7in	Pan	Flush
4in x 4in Web Angles To Web Plates	⅜in	6¼ Dia.	Pan	Flush

Description	**Diameter**	**Pitch**	**Head**	**Point**
6in x 6in Face Angles To Web Plates	1in	8in Reeled	Pan	Flush
20in Girder Stiffeners To Bulkhead	⅜in	6½in Reeled	Pan	Flush
Vertical Stiffeners – Lower To Middle Deck	¾in	5¼ Dia.	Pan	Flush
Vertical Stiffeners – Middle To Upper Deck	¾in	6 Dia.	Pan	Flush
Between 7in Double Channels	⅜in	9in Reeled	Pan	Flush

When examining this table, it will be noted that the shank diameter and pitch for the rivets which attached the foundation and deck angles to the plates of the Tank Top and the various decks were omitted from the table. This is because both the scantlings for these angles and the details for the riveting through the flange which attached them to deck plates were provided on the deck iron drawings. This was no doubt deemed necessary because the size and pitch of the riveting through the horizontal flanges of these bars were variable and changed according to the side of the bulkhead upon which they were located. In other cases, where special arrangements or patterns of riveting were required, small sketches accompanied the tables as necessary.

The most perforated transverse sections of the shell plating were in way of the lines of rivet holes associated with the boundary bars of the watertight bulkheads. Angle bars with flanges of unequal length, measuring 7in x 4in x 13⁄20in to 14⁄20in, were used to tie the bulkheads to the shell plating. In most cases, these bars were oriented with short flange against the shell plates on the side on which the bulkhead was caulked; on the opposite side of the bulkhead, where the stiffeners were located, the long flange was placed against the shell. The bulkhead boundary bars were connected to the bulkhead plates through a double row of rivets having pan-heads and snap points, and ranging from ⅜ to 1 inch in diameter on a pitch of 4 to 4½ diameters, with the heavier rivets being used throughout the mid body. To connect these bars to the shell, through the shorter flange, a single row of pan-head rivets with flush points was used, ranging from 1 to 1⅜ inches in diameter on a pitch of 4½ to 5 diameters. On the longer flange of the opposite bar, a double row of rivets was used; the row farthest from the bulkhead was identical in size and pitch to the riveting through the shorter shell flange, while the pitch of the row closest to the bulkhead, which used the same size and type rivets, was increased to double the pitch of the outer row.

To compensate for the loss of strength created by the boundary bar riveting, and also to fill the space between the plates of the 'out' strakes and the bars, short doublers called 'bulkhead liners' were introduced on the inboard sides of the 'out' strakes in way of each watertight bulkhead. In most locations, these liners were made just wide enough to introduce an additional row of rivets ahead or abaft of the line of rivets attaching the boundary bars on either side of each bulkhead. The outer rows of rivets were placed on a coarser pitch like those rivets of the inner row of the double rivets securing the longer flanges and were staggered to avoid creating straight lines of holes which might encourage stress fracturing.

All bulkheads were caulked to ensure watertightness. However, it was only necessary to do this on one side. The collision bulkhead was caulked on the after side and the aftermost bulkhead on the fore side. This same rule applied to all bulkheads forming the boundaries of deep water-ballast tanks; the caulking was carried out on that side of the bulkhead which was the outside of the tank. For other bulkheads, it was immaterial which side was caulked, but it was carried out on the side on which the rivets had been hammered up, or, in other words, the side opposite that to which the stiffeners were attached. As can be seen in the profile views within the accompanying bulkhead figures in this chapter, the side of the bulkhead on which this work was carried out could switch more than once within the same bulkhead, as the side on which the stiffeners were placed could be changed to suit the design requirements both of the ship's structure and her machinery.

The watertight bulkheads were tested by the Board of Trade surveyor with a feeler gauge at the seams; those forming part of the peak tanks were tested for efficiency and watertightness in the yard by filling them with water to the height of the load line. This was done to detect more readily where the caulking was faulty.

Vertical-sliding watertight doors

The vertical sliding watertight doors giving communication between the various compartments at the Tank Top level were arranged on the drop system. They were designed by Harland & Wolff, made of cast iron of heavy section and worked on the 'geared' system. These doors were fitted in two distinct sizes, with the doors through WTBs D through J having a clear opening measuring 5ft 6in high by 4ft 0in wide, while the doors at WTB K and aft were narrower, having a clear opening of 5ft 6in x 2ft 9in. The wider doors were employed throughout the boiler rooms to deal with the large numbers of men passing through these compartments during each change of watch, and also to permit the passage of wheel barrows.

A cast-iron frame was fitted to the bulkhead providing a fairly loose-fitting groove that allowed the door to slide freely up and down. On the external face of the doorplate, forming part of the casting, were a number of tapered wedges. In the door frame were a number of lugs with machined undersides forming corresponding wedges tapered in the same direction, so that the two wedges would fit together. There were six wedges on each side, 12 in all; as the door came down, it was free to move until the wedges were opposite their corresponding lugs in the frame; then the wedges would engage and tightly drive the machined rear surface of the door against the machined surface of the frame. When these two carefully machined and lapped surfaces were forced together they created a watertight joint.

With the exception of the last 18 to 24in, the doors did not fall like a guillotine, but descended gradually, requiring twenty-five to thirty seconds to close. The heaviest of these doorplates weighed about 15cwt (1,680lb). In order to prevent any possibility of a man being caught in the door as it descended, hydraulic cataract cylinders similar to a gun recoil cylinder were arranged so that the speed of the door's descent was comparatively slow, depending on the amount of fluid allowed through a metered orifice in the piston within the cylinder. A single cylinder was provided for each of the narrower doors, while a pair were fitted above each of the wider doors in order to deal with the greater weights involved. For the last 18 to 24in, a fluid bypass around the piston came into action, freeing the door to fall quickly. This would easily cut in two or push aside any ordinary obstruction.

Each vertical-sliding door was held in the open position by a horizontal shaft supported on bearings affixed to either side of the door frame. A pinion gear, which meshed with a vertical gear rack cast into the external face of the doorplate, was keyed to the middle of the shaft. Attached to one end of this gear shaft was a multiple-disc friction clutch similar in principle to

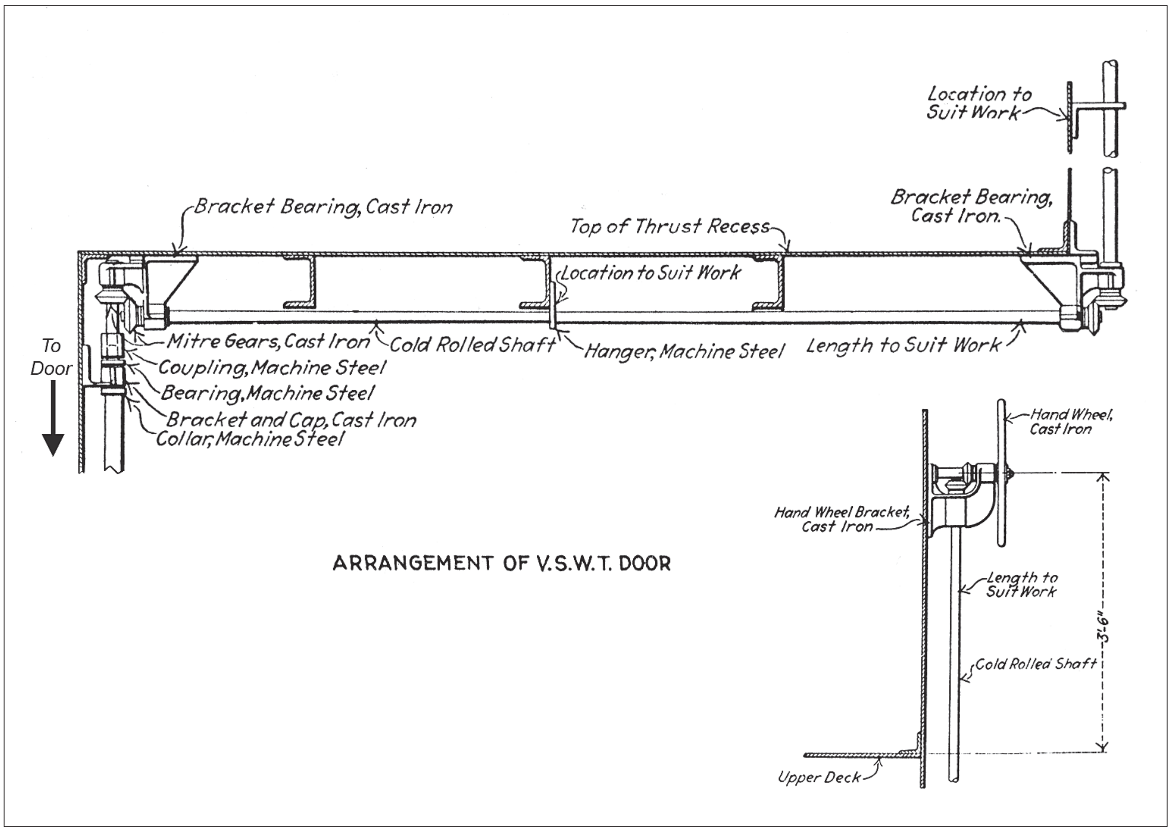

Location to Suit Work
Bracket Bearing, Cast Iron
Top of Thrust Recess
Bracket Bearing, Cast Iron.
Location to Suit Work
To Door
Mitre Gears, Cast Iron
Cold Rolled Shaft
Hanger, Machine Steel
Length to Suit Work
Coupling, Machine Steel
Bearing, Machine Steel
Bracket and Cap, Cast Iron
Collar, Machine Steel
Hand Wheel, Cast Iron
Hand Wheel Bracket, Cast Iron
ARRANGEMENT OF V.S.W.T. DOOR
Length to Suit Work
3'-6"
Cold Rolled Shaft
Upper Deck

Fig. 6-4 **Watertight Door Remote Hand Gear** – This drawing shows the features typical of the hand gear fitted to operate a watertight door from one or more decks above the door. In this instance, a hand wheel is shown at the bulkhead deck level, but the arrangement of shafts and gears shown here is also typical of the hand gear that terminated at the recessed deck plates present on E and D decks approximately above the door locations.

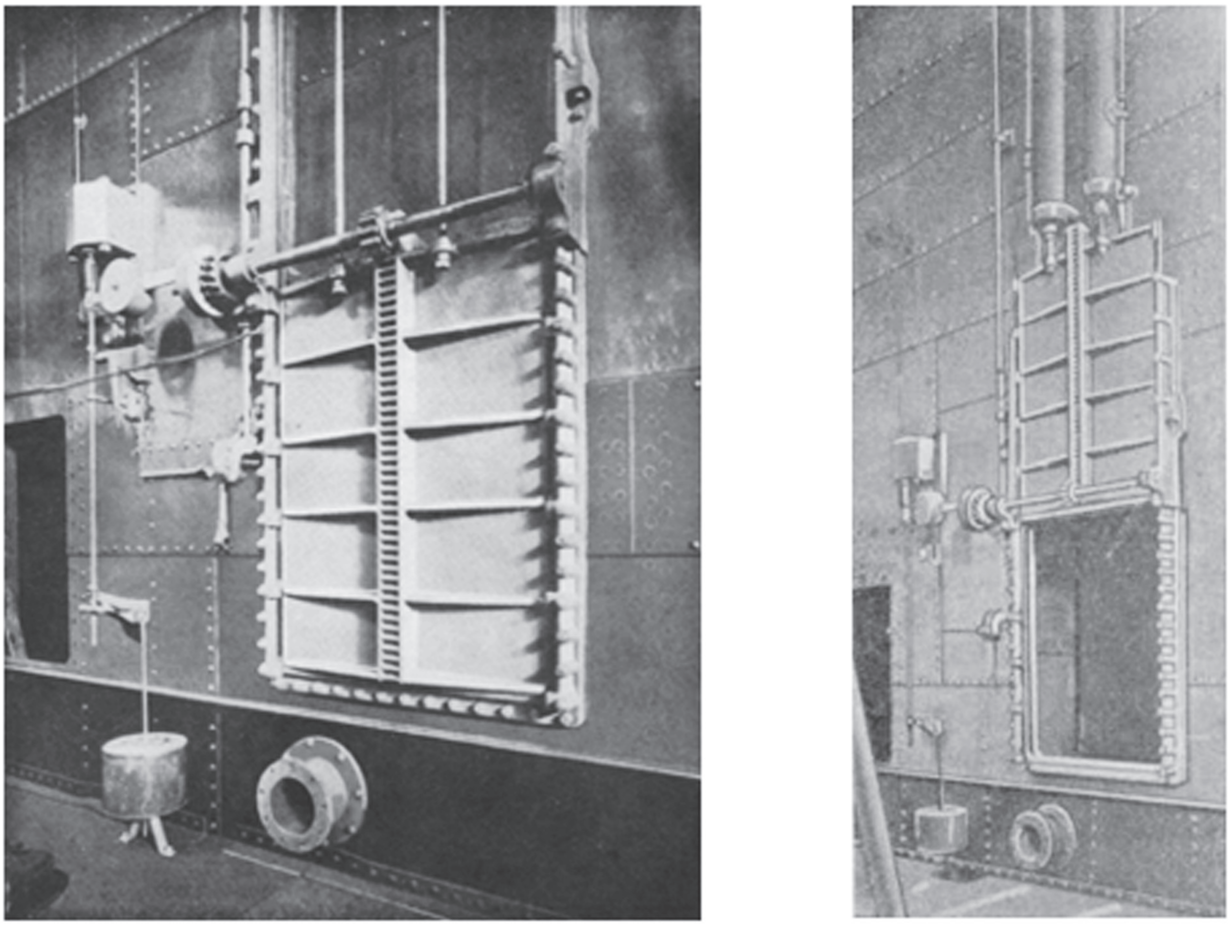


Fig. 6-5 **Vertical-Sliding Watertight Door** – These two images are what appears to be the same watertight door on *Olympic*; this is one of the wider, double-cylinder doors fitted throughout the boiler rooms. At left, the float is to the left of the door below a horizontal line which indicates the height of the as-yet-to-be-fitted stokehold deck plates above the Tank Top. The image at right shows more of the area above the door, including part of the two hydraulic cataracts which checked the speed of descent of the door. *(Left image:* The Shipbuilder*/Authors' collection; Right image private collection)*

those used in the drive train of motor vehicles of the period. The discs within this clutch were kept locked together by a weighted bell crank. As long as there was a weight applied through the bell crank lever, contact between the rotating friction discs keyed to the gear shaft of the door and the fixed friction discs within the clutch housing was maintained, thereby preventing the doorplate from moving. The doors were held in the raised position simply by the fixed discs being locked against the discs keyed to the gear shaft of the door. Lifting the weighted bell crank lever caused the release of the pressure on the discs, which then permitted the shaft to rotate freely, allowing the door to descend.

The clutch for each of the vertical-sliding doors could be instantly released by a powerful solenoid. The switch lever for remotely releasing the doors was located on the Navigating Bridge. All one had to do was to pull the lever over in a circular motion; this action closed an electrical switch and energized the solenoids, releasing all of the doors simultaneously. There was no centrally located device to close the doors independently of one another, nor was there an indicator panel to show the status or positions of the doors. This type of device would not be installed on the *Olympic* until after the sinking of *Titanic*.[1] A bell push located within close proximity of the release lever was pushed immediately before the lever was pulled to lower the doors. This button activated warning bells at each door location below.

In addition to being remotely operable, these doors could also be closed locally by lifting a hand lever fitted

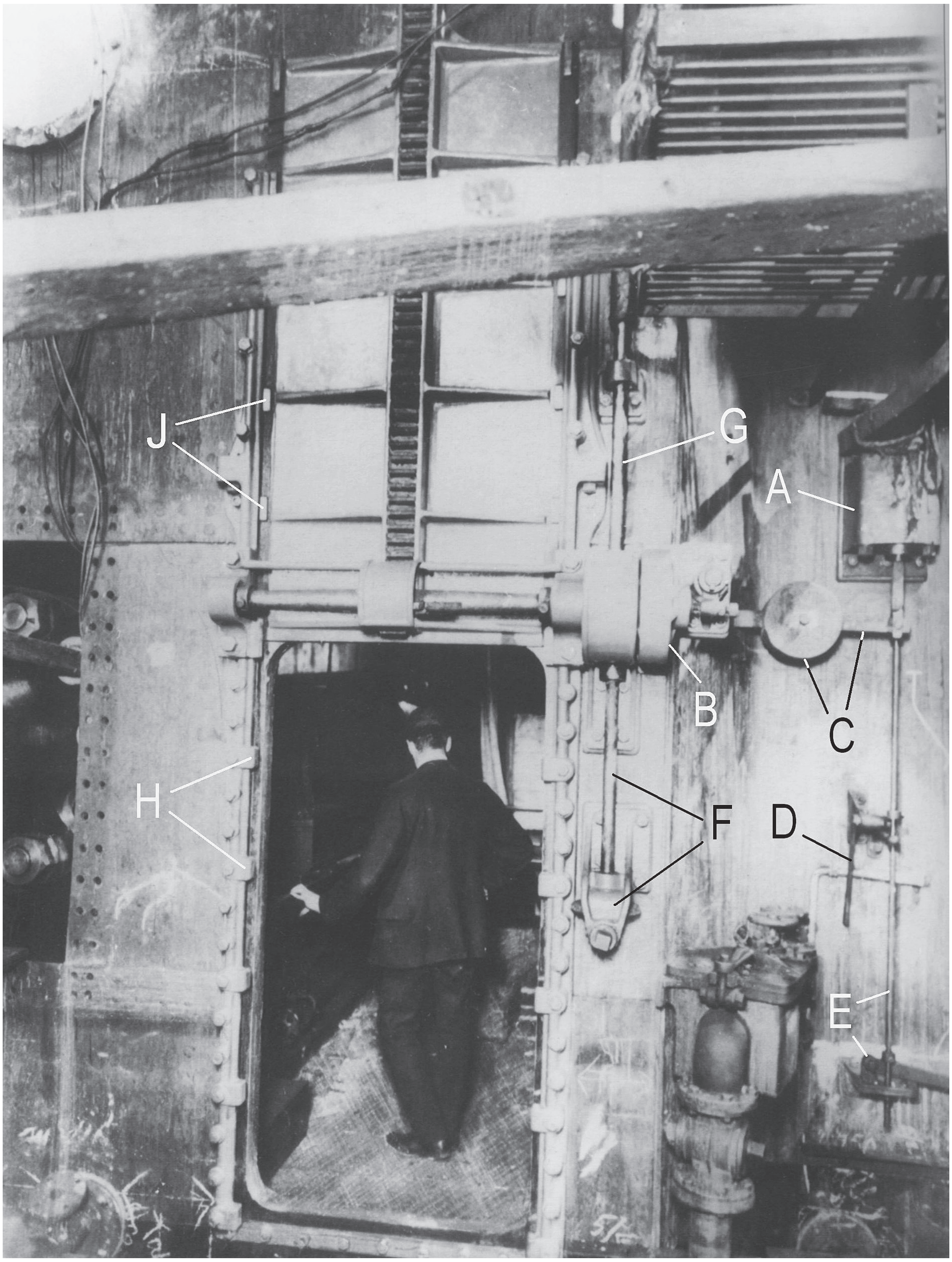


Fig. 6-6 **Vertical-Sliding Watertight Door** – Another view of a watertight door on *Olympic* showing a bit more detail; the door shown in this photo is the one through WTB M, shown looking from the Turbine Engine Room aft into the Electric Engine Room. At the left of the image, part of the starboard wing shaft can be seen, visible through an opening in the bulkhead which will soon be closed up around the shaft with bolted plates and and a watertight gland. Clearly visible to the right of the door are the solenoid (A), friction clutch (B), weighted bellcrank (C), and hand releasing lever (D), as well as the rod and lever from the actuating float (E) located below the deck plates of the compartment. Below the clutch, the gears and shaft of the hand raising gear (F) may be seen, while above the clutch is the remote operating shaft leading to the bulkhead deck above (G). Also visible in this image are the lugs (H) on the door frame and the corresponding wedges (J) on the door plate. *(H&W/Authors' collection)*

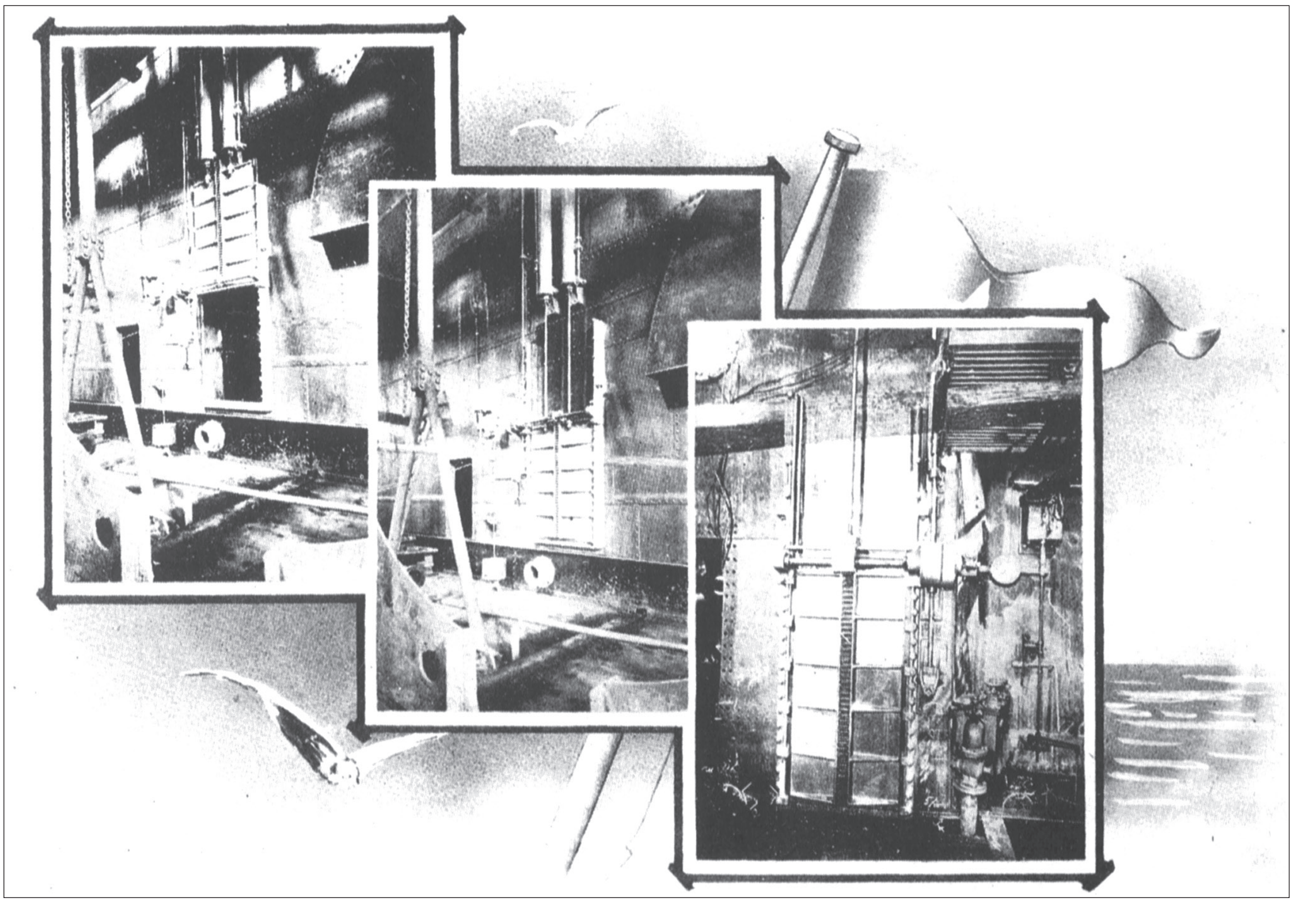


Fig. 6-7 **Watertight Door From Brochure** – A series of photos from a White Star Line brochure showing one of *Olympic*'s watertight doors in different stages. The hydraulic checking cataracts above the door can be seen. Also visible in two of these pictures are portions of the boiler seats in the foreground (with lightening holes), and one of the inverted Y-shaped stanchions, all of which make these images rather interesting.

in connection with the friction clutch on the fore side of the door. A hand gear for each door was also fitted at the bulkhead deck above. The mechanism consisted of a rod going down as nearly vertical as possible to the door. The rod had on its lower end a worm, geared into a worm wheel on the door shaft, allowing the door to be lowered or raised by manual means.

As a further precaution, hollow cylindrical floats measuring 12in high by 18in in diameter were provided beneath the stokehold deck plates; in the event of water entering any of the compartments unnoticed, these floats automatically lifted the clutch levers, thereby closing the doors opening into that compartment. A rise of water 18 to 24in above the Tank Top plates was sufficient to release the corresponding door. At each door, a hand gear was fitted to manually raise the door using a crank handle.

It has often been published incorrectly that *Titanic*'s watertight doors were operated by hydraulic power. As stated above, *Titanic*'s electrically-released watertight doors closed by the force of gravity alone; the speed of the descent was merely checked by hydraulic cataracts. Misunderstanding of the function and purpose of the hydraulic cataracts employed in Harland & Wolff's vertical-sliding watertight doors has often led to confusion with the Stone–Lloyd system of hydraulically-controlled watertight doors, which was employed most notably in the larger Cunard vessels of the era; in that system, hydraulic power was used both to close and then re-open the watertight doors.[2] In the case of the *Olympic*-class vessels however, once the friction clutches were released and the doors closed, the only way to raise them again was by the use of hand power by turning a crank alongside the door which was geared to the gear shaft of the door.

A ladder or escape was provided in each boiler room, engine room and similar watertight compartment in order that the closing of the doors at any time would not imprison the men working inside. The escapes associated with the boiler rooms led from the boiler casings either into the working passage on E Deck, or to the level of the Boat Deck through ladders fitted within the fidley casings, while similar ladders and platforms within the casings above the engine rooms provided a means of accessing the Boat Deck from these compartments.

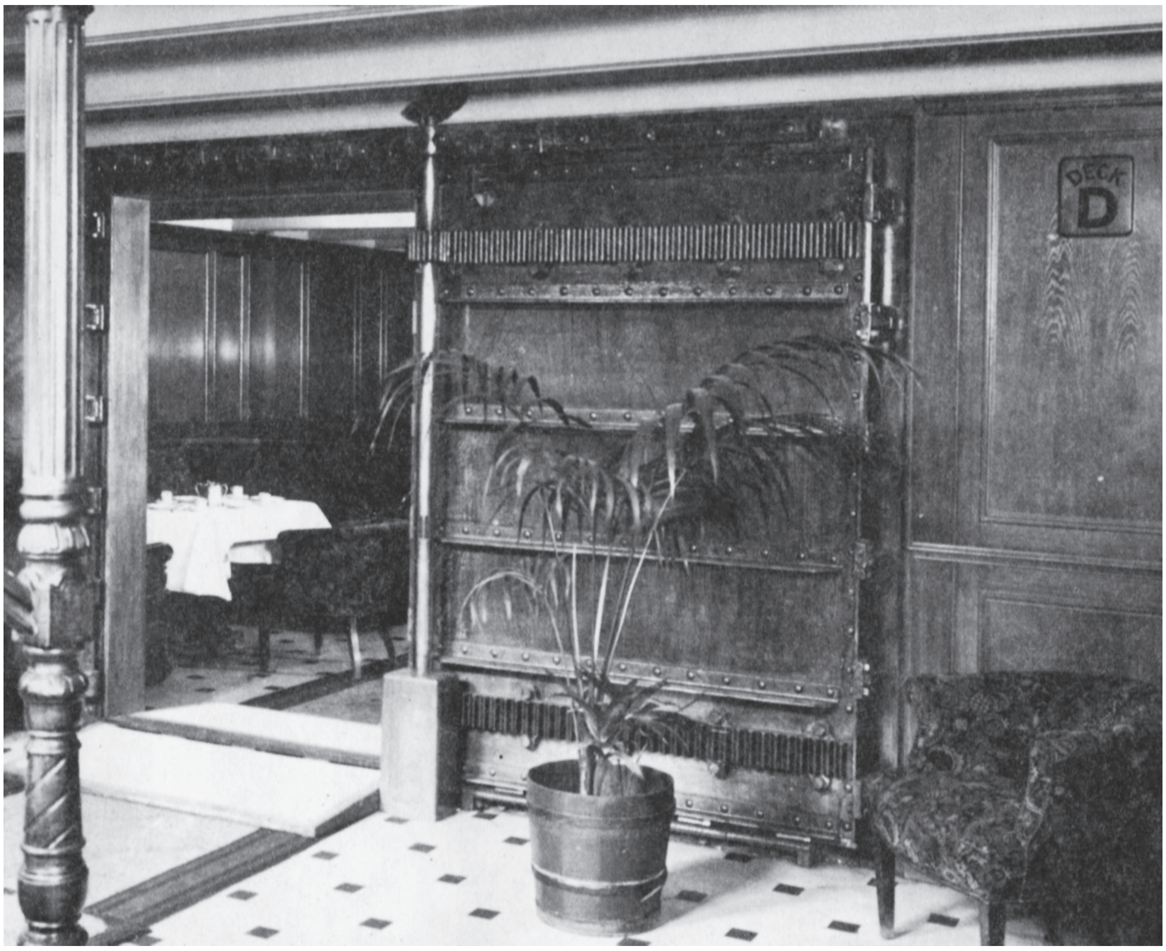


Fig. 6-8 **Lateral-Sliding Watertight Door** – Adriatic – A rather large lateral-sliding watertight door aboard the White Star Line's *Adriatic* (1907). This one was located at the entrance to the Dining Saloon; note how the door has been *faux*-painted with a wood-grain pattern in an attempt to help it better blend in with its surroundings. *Olympic* and *Titanic* had many watertight doors similar in construction to this one. *(H&W/Authors' collection)*

Horizontal- or 'lateral'-sliding watertight doors

The watertight doors on D and E Decks were of the horizontal- or lateral-sliding pattern, with wrought-steel doorplates, and operating on the 'rack and pinion' system. Those doors below E Deck were similar in design, but had strongly ribbed cast iron doorplates of heavy section.

The door frames were cast with projecting 'fitting-strips' on the side facing the bulkhead; being narrow, these could easily be chipped by hand to fit over and tightly conform to the irregularities of the bulkhead. The guide grooves for these doors were formed by flat, wrought-iron face pieces which, while secured by the same bolts that held the frame to the bulkhead, could be taken off without disturbing the latter, which facilitated the planing and scraping of the contact surface in the groove. The top and bottom grooves and the corresponding edges of the door were slightly tapered so that when the door was closed, it would be pressed into watertight contact with the cast-iron frame. When the door was open, the thin part of its edge was in the wide part of the groove.

Around the margin of the door, where it pressed against the cast-iron frame when closed, parallel strips of brass were riveted. These strips and the frame were machined to form perfect contact surfaces that fit accurately upon one another. Wedges were fitted to the edges of the door along the top and bottom, and to the vertical edge opposite the shaft. As the door was cranked shut, the wedges on the doorplate came into contact with mating tapered wedges which were cast and machined into the door frame, causing the machined contact faces of the doorplate to bear down tightly against the brass strips within the door frame, resulting in a watertight seal. For the back edge of the door, there was no vertical frame member present to provide the type of cast-in-place wedges which sealed the leading edge. Instead, it was pressed against the door frame

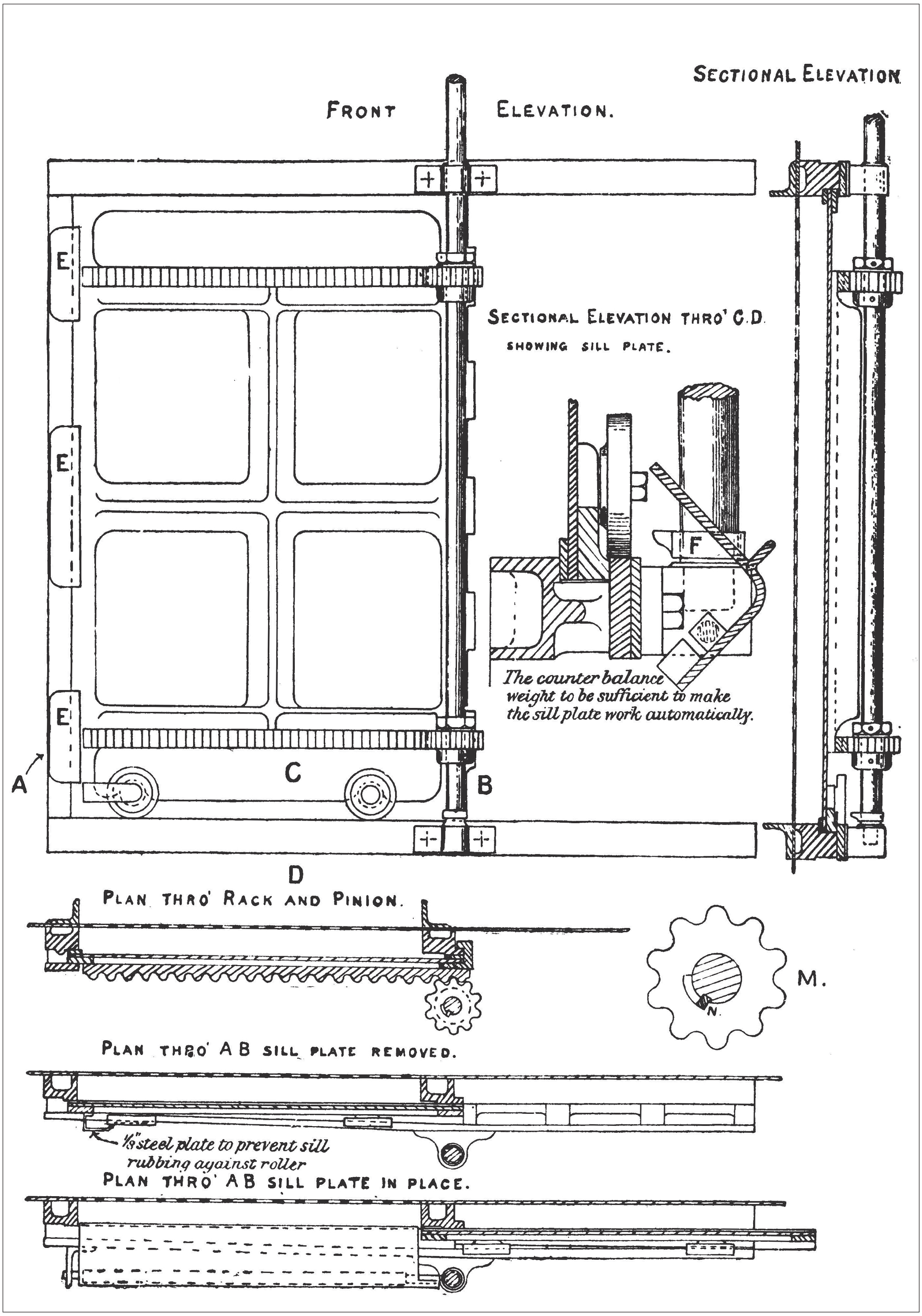

SECTIONAL ELEVATION
FRONT ELEVATION.
SECTIONAL ELEVATION THRO' C.D
SHOWING SILL PLATE.
E
E
E
F
A
C
B
D
The counter balance weight to be sufficient to make the sill plate work automatically.
PLAN THRO' RACK AND PINION.
M.
N.
PLAN THRO' A B SILL PLATE REMOVED.
1/8" steel plate to prevent sill rubbing against roller
PLAN THRO' A B SILL PLATE IN PLACE.

Fig. 6-9 **Lateral-Sliding Watertight Door** – A drawing of a typical lateral-sliding watertight door of the era. While the design details differ somewhat from those on *Titanic*, the principle components are the same. Note the automatic sill cover which prevented dirt and debris generated by foot traffic from collecting in the lower track of the door. *(Scott Andrews collection)*

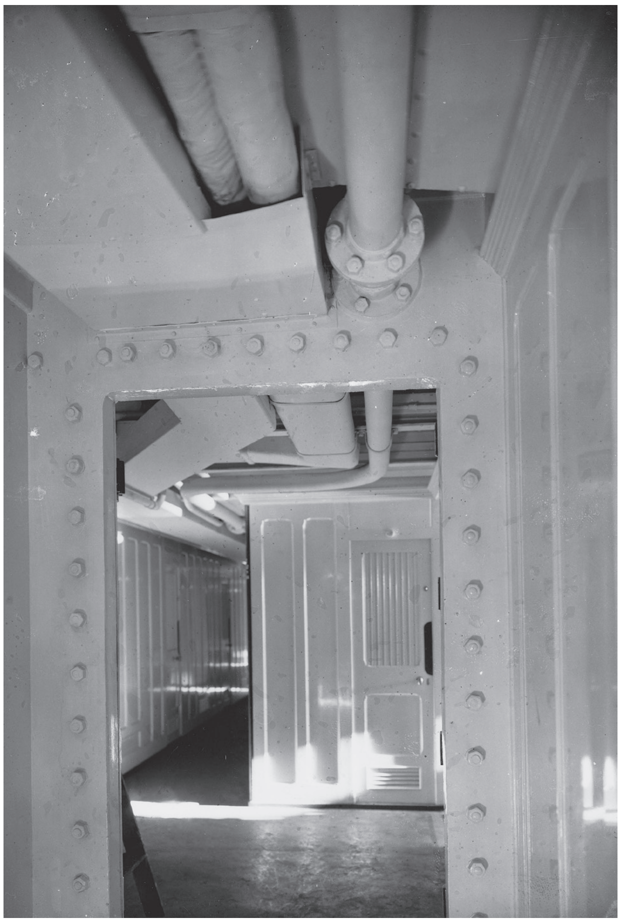


Fig. 6-10 **Lateral-Sliding Watertight Door Opposite of Mounting Side** – This image, taken in a passageway on E Deck, shows a lateral-sliding watertight door viewed from the back side. This is the view one would see on the side of the bulkhead opposite the door. *(H&W/Authors' collection)*

by the shaft. This was accomplished by locally increasing the projection of the racks so that as the door was closed, a cam action was produced and the pinion wheels would press the back edge of the doorplate tightly against the sealing strip. To reduce friction, the horizontal doors were provided with a couple of small wheel casters along their bottom edge.

The lateral doors were designed to be cranked shut both locally and from the bulkhead deck above. The controlling shafts for the lateral doors passed into a recessed brass deck plate, 10 to 12in in diameter, fitted flush with the deck. This was covered with a brass flush-fitting plug or cover plate which was unscrewed by means of the two-forked end of a pin spanner which exposed the end of the shaft. Removing the cover plate exposed the end of the control shaft, formed in the shape of a square or hexagonal pin, to accept the socket end of the 30in-long T-handle box key used to rotate the shaft.

To facilitate the quick closing of the doors from the bulkhead decks, cast brass plates were provided to indicate the positions of the deck plates. Bearing the words 'WT DOOR DECK PLATE' and an arrow pointing to the approximate location, these were affixed in suitable positions on the sides of the alleyways and in spaces such as public rooms, on columns or other nearby surfaces. Box keys were provided for each door, hanging in suitable clips alongside these bulkhead indication plates.

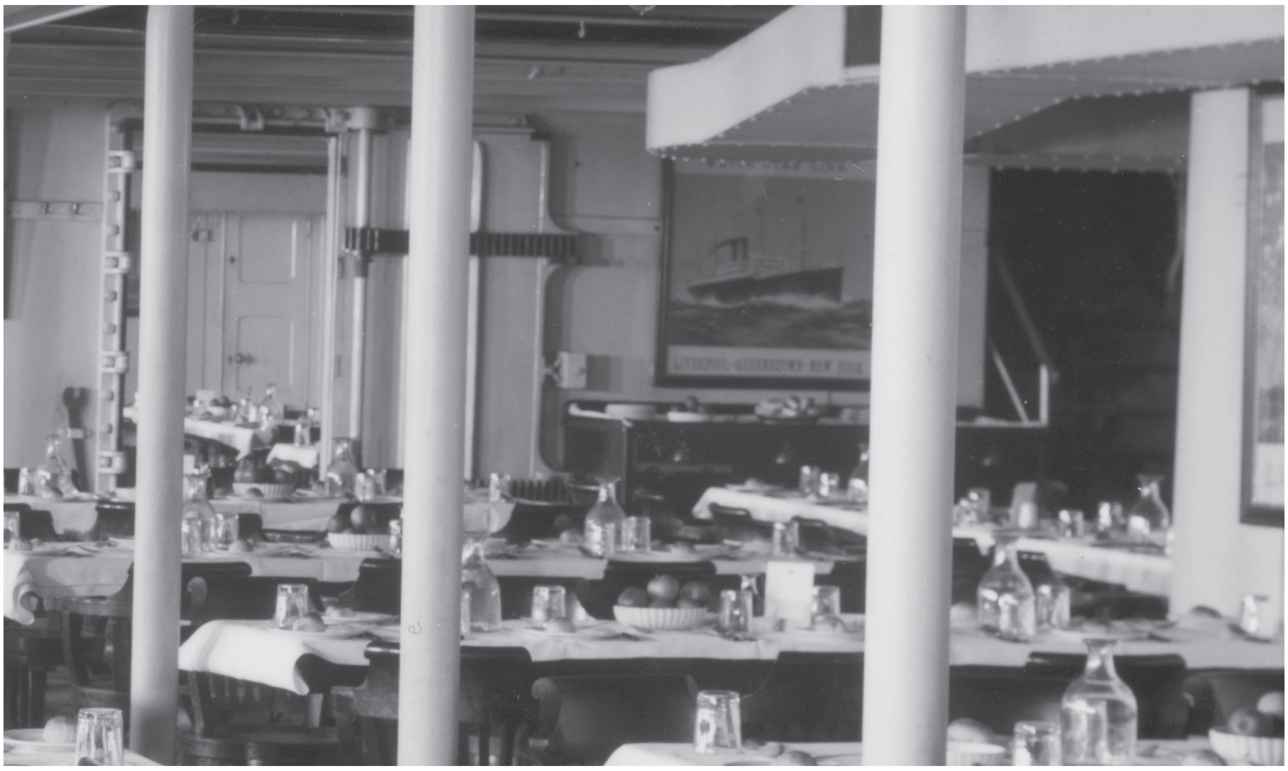


Fig. 6-11 **Lateral-Sliding Watertight Door on *Olympic*** – One of the two 6ft 6in x 3ft 0in lateral-sliding watertight doors through WTB H in *Olympic*'s Third Class Dining Saloon. *(Daniel Klistorner collection)*

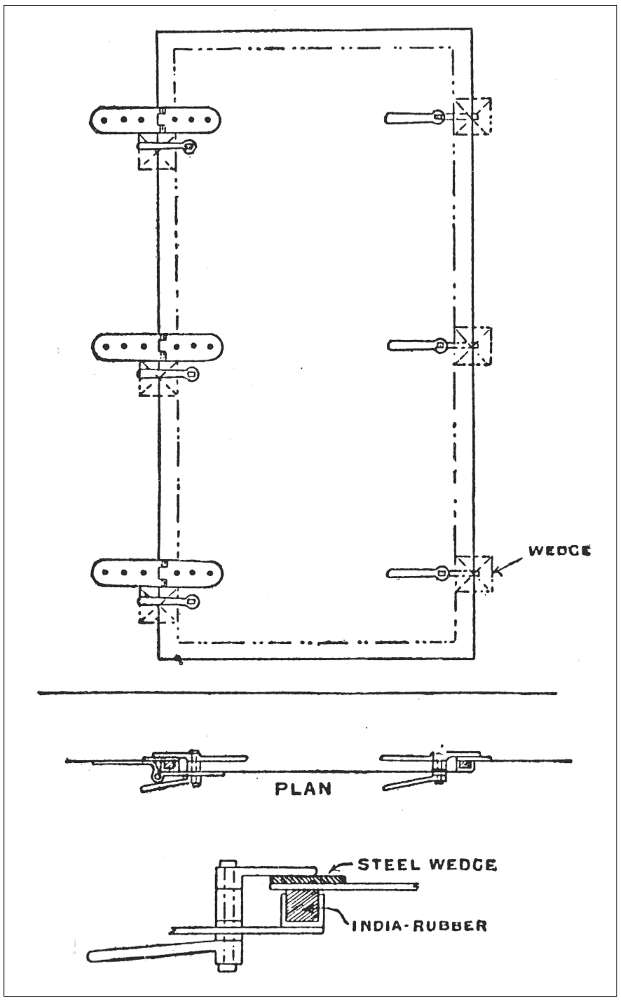


Fig. 6-12 **Drawing of Hinged Watertight Door** – Details of a basic Admiralty-pattern hinged watertight door. A door of this type could either have the ‘dogs’ attached to the door, or on the bulkhead. In this instance, the dogs are fitted on the door plate, similar to the doors seen in the Well Decks.

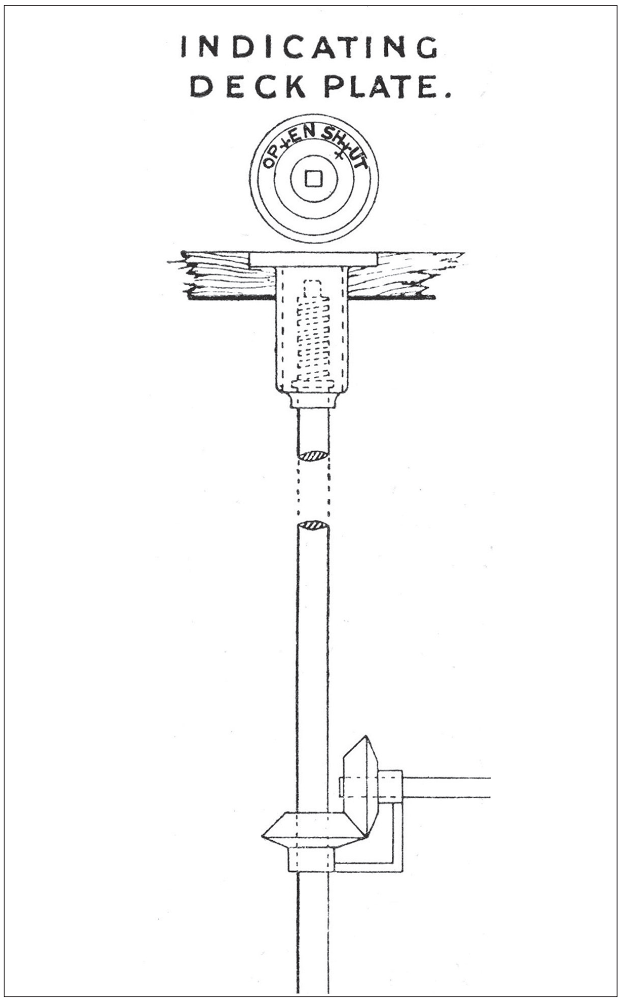


Fig. 6-13 **‘Indicating’ Deck Plate for Watertight Door** – An example of a typical indicating deck plate that would be fitted into the bulkhead deck above the position of a watertight door. The gears shown at the midpoint of the vertical shaft indicate how a secondary connection such as an auxiliary hand wheel or crank would be fitted on an intervening deck between the bulkhead deck and the deck on which the door was located.

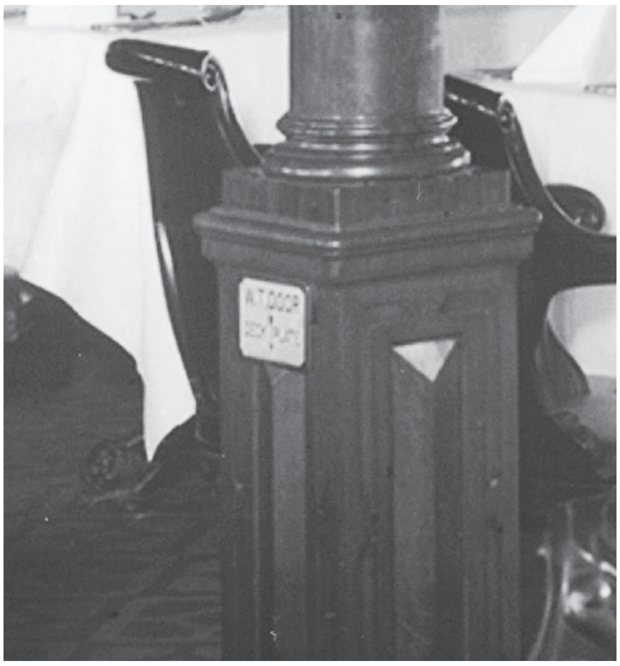


Fig. 6-14 **Deck Plate Identification Plaque** – An identification plaque marking the presence of a watertight door deck plate nearby to this column in the Second Class Dining Saloon on D Deck. The raised lettering of this cast brass plaque reads ‘WT Door Deck Plate;’ in the center of the lettering is an arrow, pointing down towards the approximate location of the plate. *(Daniel Klistorner collection)*

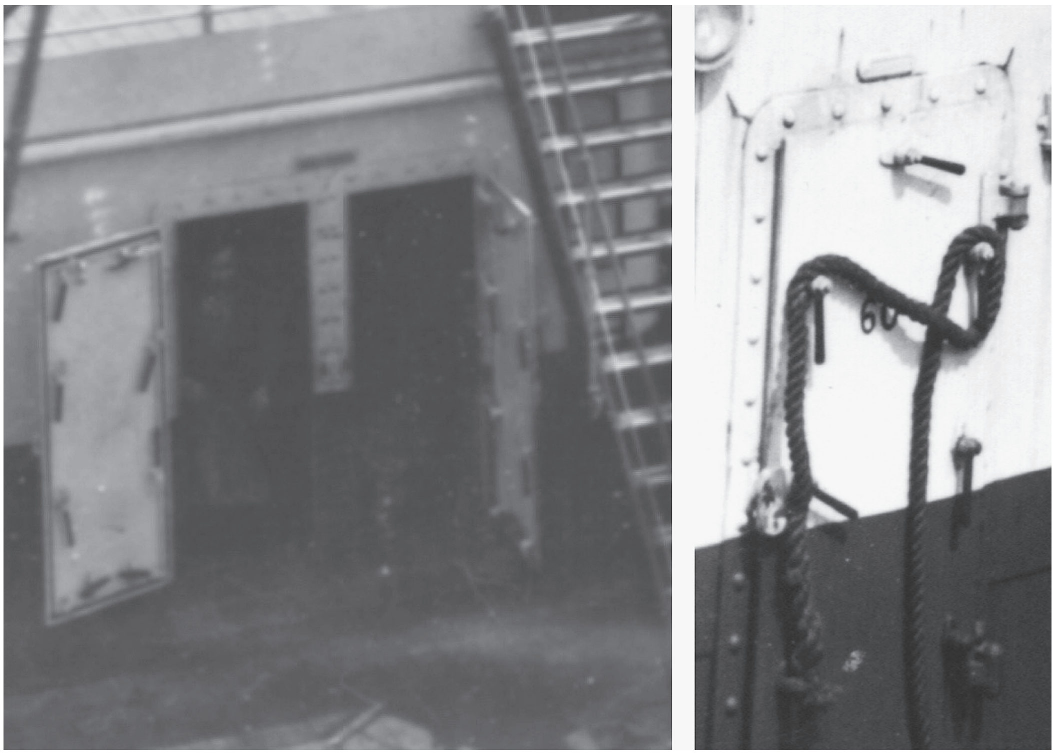


Fig. 6-15 **Hinged Watertight Doors – *Olympic*** – Two images of hinged watertight doors aboard *Olympic*. The image to the left is from the forward Well Deck, while the one to the right is from one of the crane bases in the after Well Deck. These are examples of the hinged watertight doors which were located on the ship's weather decks; while no photos or specific design details have surfaced regarding the hinged watertight doors fitted in *Titanic's* watertight bulkheads, the design and appearance of those doors would have been very similar to these examples.

Watertight doors of the vertically hinged type were also employed aboard *Titanic*, both on the weather decks and, in a few instances, through the watertight bulkheads as well. Two such doors were located within the watertight vestibule at the aft end of the Firemen's Passage[3] running between No.6 Boiler Room and the crew's spiral staircases immediately aft of WTB B. (These two doors, which provided access from the boiler rooms into the reserve coal bunker space, were normally kept closed while the vessel was at sea.) Doors of this type were fitted with a series of handles, or 'dogs', and achieved watertightness by tightly compressing a rubber gasket between the doorplate and a lip on the door frame.

General Overview of Titanic*'s Watertight Bulkheads*

In the specifications which follow, information has been added to clarify the physical characteristics of the watertight bulkheads. Within the description of each bulkhead, a very brief list of the principal spaces bounded by each bulkhead is provided; a more thorough understanding of the various compartments and accommodations bounded by any particular bulkhead can best be understood by viewing general arrangement plans.

Included within the report issued by the Board of Trade after the inquiry into the loss of *Titanic* were measurements between watertight bulkheads forming adjacent compartments. These measurements have been included here – with some adjustments made for the sake of accuracy – to help illustrate the sizes of these compartments. As stated above, commencing from forward, the watertight bulkheads were designated 'A' through 'P', exclusive of 'I'.

The illustrations of the individual watertight bulkheads which accompany this chapter were traced from the original Harland & Wolff drawings. Because the original drawings are quite old and have been copied and mishandled over the years, some skewing and stretching of the original muslin tracing cloth has taken place. While these tracings show some of the distortions present in the original drawings, they have been corrected to some degree. The figures which accompany this chapter have also been highly simplified, with much of the fine detail omitted for the sake of clarity. The originals, which were drawn in $^{1}/_{48}$ scale, are large enough to permit the inclusion of many small details and notations, all of which were absolutely necessary to convey the intentions of the designers to the various shops and tradesmen. However, with the reduction in size required for this text, many of these small details would have been reduced to the point of being indecipherable smudges, and so were eliminated to provide the reader with a clear representation of the most significant details of each bulkhead. Of particular note in this instance are the omission of the vertical lines representing the position of the vertical stiffeners in the transverse elevations; while these lines were eliminated from the majority of the transverse elevations presented here, they were retained for WTB K to give the reader an appreciation of the nature and extent of the network of stiffeners which reinforced these bulkheads, and also to demonstrate the almost completely illegible result which inclusion of these lines would add to a drawing reduced to the scale permitted by the size of this volume.

Per standard drafting conventions, dashed lines indicate the outline of an object, or an edge 'behind' what is shown, while solid lines indicate the visible objects and edges within a view. Plating thicknesses have been indicated when they are present on the original drawings. In many cases, the bulkhead plates mirrored each other about the ship's centerline so that it was not considered necessary to repeat the thicknesses on both sides. In other cases, the thickness of the plates within a strake were omitted by the draftsman, indicating that, unless noted otherwise, the thickness noted on the profile view, or on a single marked plate within the strake, was the same for all plates throughout the entire strake. Also shown in these

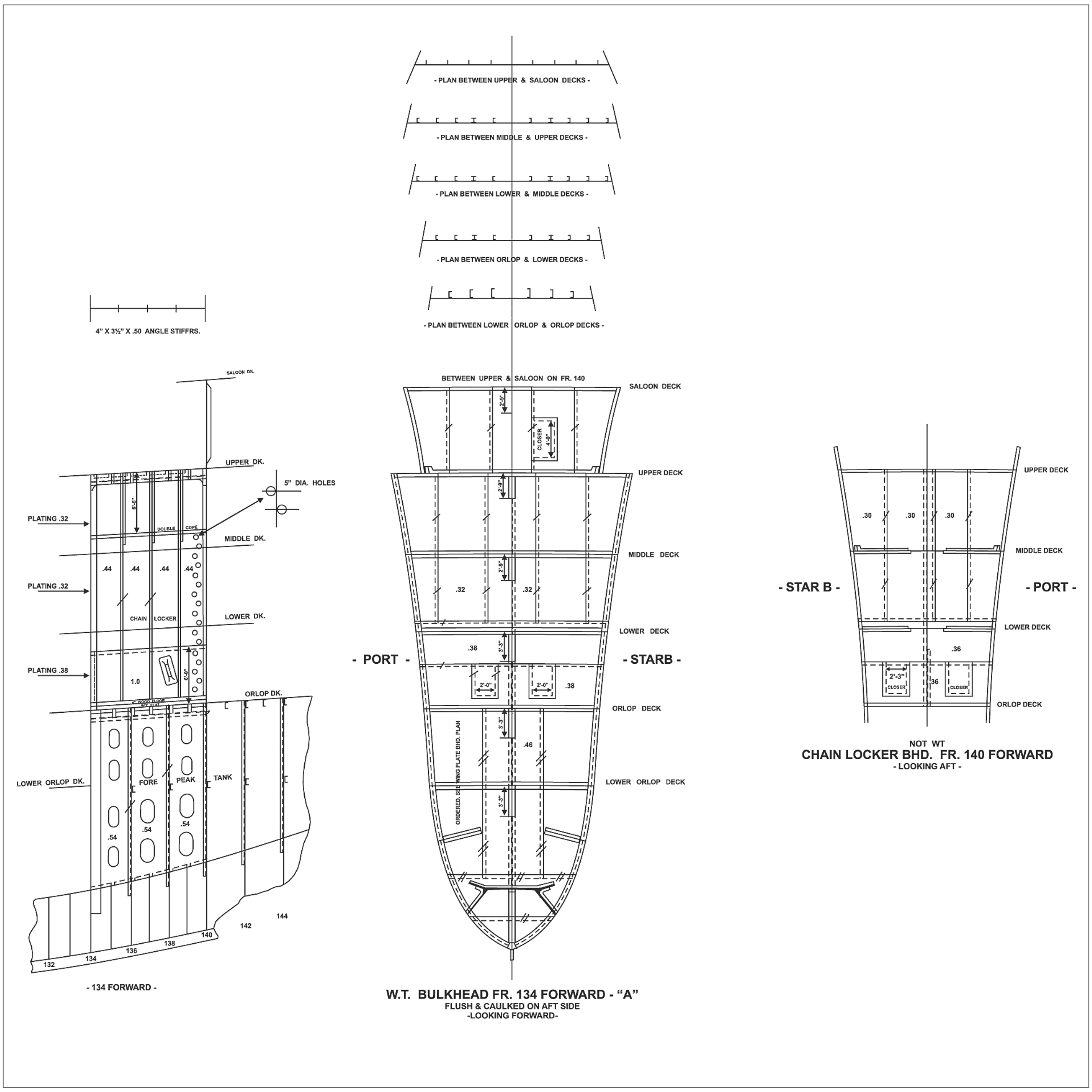

- PLAN BETWEEN UPPER & SALOON DECKS -
- PLAN BETWEEN MIDDLE & UPPER DECKS -
- PLAN BETWEEN LOWER & MIDDLE DECKS -
- PLAN BETWEEN ORLOP & LOWER DECKS -
- PLAN BETWEEN LOWER ORLOP & ORLOP DECKS -
4" X 3½" X .50 ANGLE STIFFRS.
SALOON DK.
UPPER DK.
5" DIA. HOLES
6'-6"
DOUBLE COPE
PLATING .32
MIDDLE DK.
.44
.44
.44
.44
PLATING .32
CHAIN LOCKER
LOWER DK.
PLATING .38
1.0
6'-0"
4" WOOD FLOOR
W.T. FLAT
ORLOP DK.
LOWER ORLOP DK.
FORE PEAK TANK
.54
.54
.54
132
134
136
138
140
142
144
- 134 FORWARD -
BETWEEN UPPER & SALOON ON FR. 140
SALOON DECK
2'-9"
CLOSER
4'-0"
UPPER DECK
2'-9"
MIDDLE DECK
2'-9"
.32
.32
LOWER DECK
.38
3'-3"
- PORT -
- STARB -
2'-0"
2'-0"
.38
ORLOP DECK
3'-3"
.46
ORDERED. SEE WING PLATE BHD. PLAN
LOWER ORLOP DECK
3'-3"
W.T. BULKHEAD FR. 134 FORWARD - "A"
FLUSH & CAULKED ON AFT SIDE
-LOOKING FORWARD-
UPPER DECK
.30
.30
.30
MIDDLE DECK
- STAR B -
- PORT -
LOWER DECK
.36
2'-3"
CLOSER
36
CLOSER
ORLOP DECK
NOT WT
CHAIN LOCKER BHD. FR. 140 FORWARD
- LOOKING AFT -

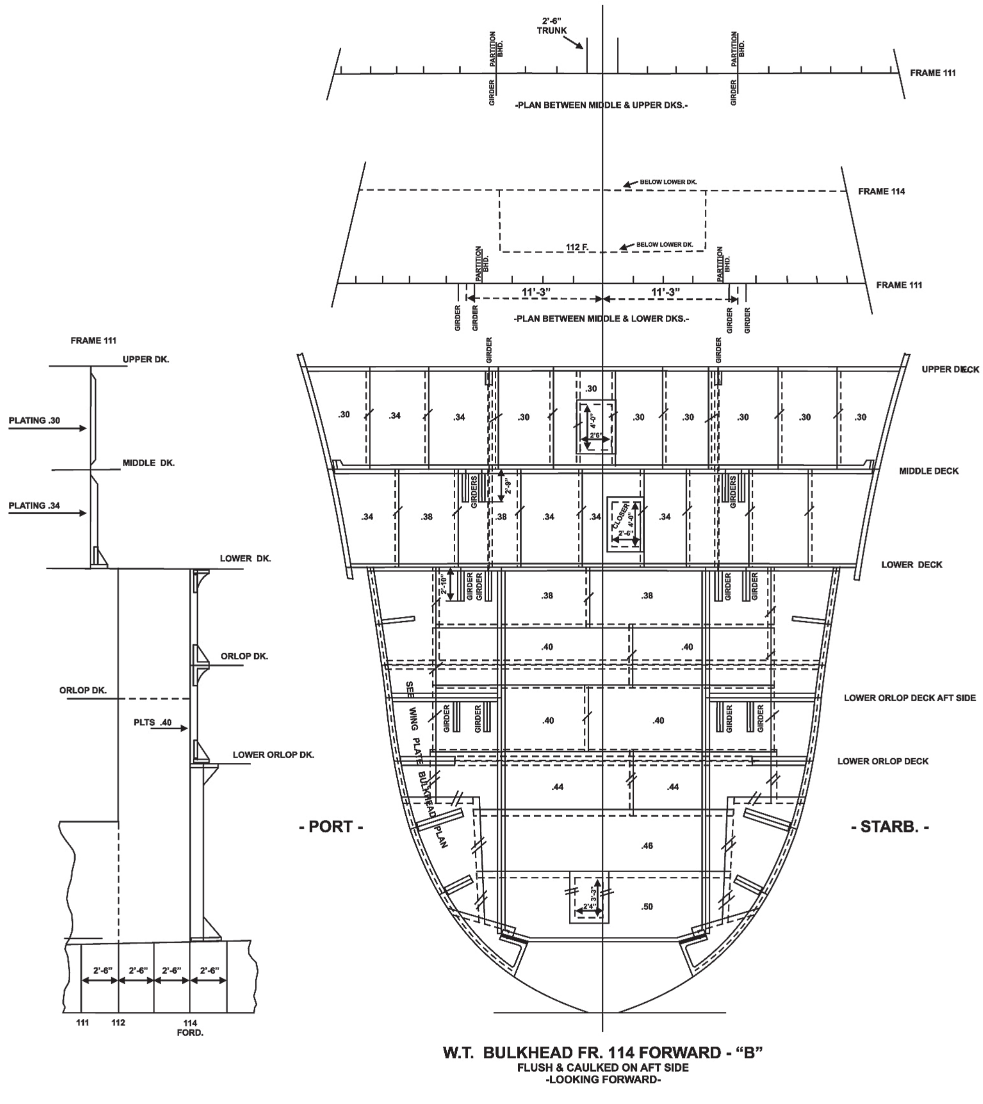
Fig. 6-16 (a) through 6–16 (o) **Watertight Bulkheads** *(Illustrations by Bruce Beveridge based on original H&W bulkhead plans)* renderings are plan views of the bulkheads in way of the upper decks, which show the orientation and composition of the reinforcing stiffeners. Plan views have been omitted for the lower decks with the exception of WTB M, which was included to show the recess created at the after end of the Turbine Engine Room to provide space for the center shaft bulkhead gland and the seats of the after turbine rotor bearing.

Chain Locker Bulkhead

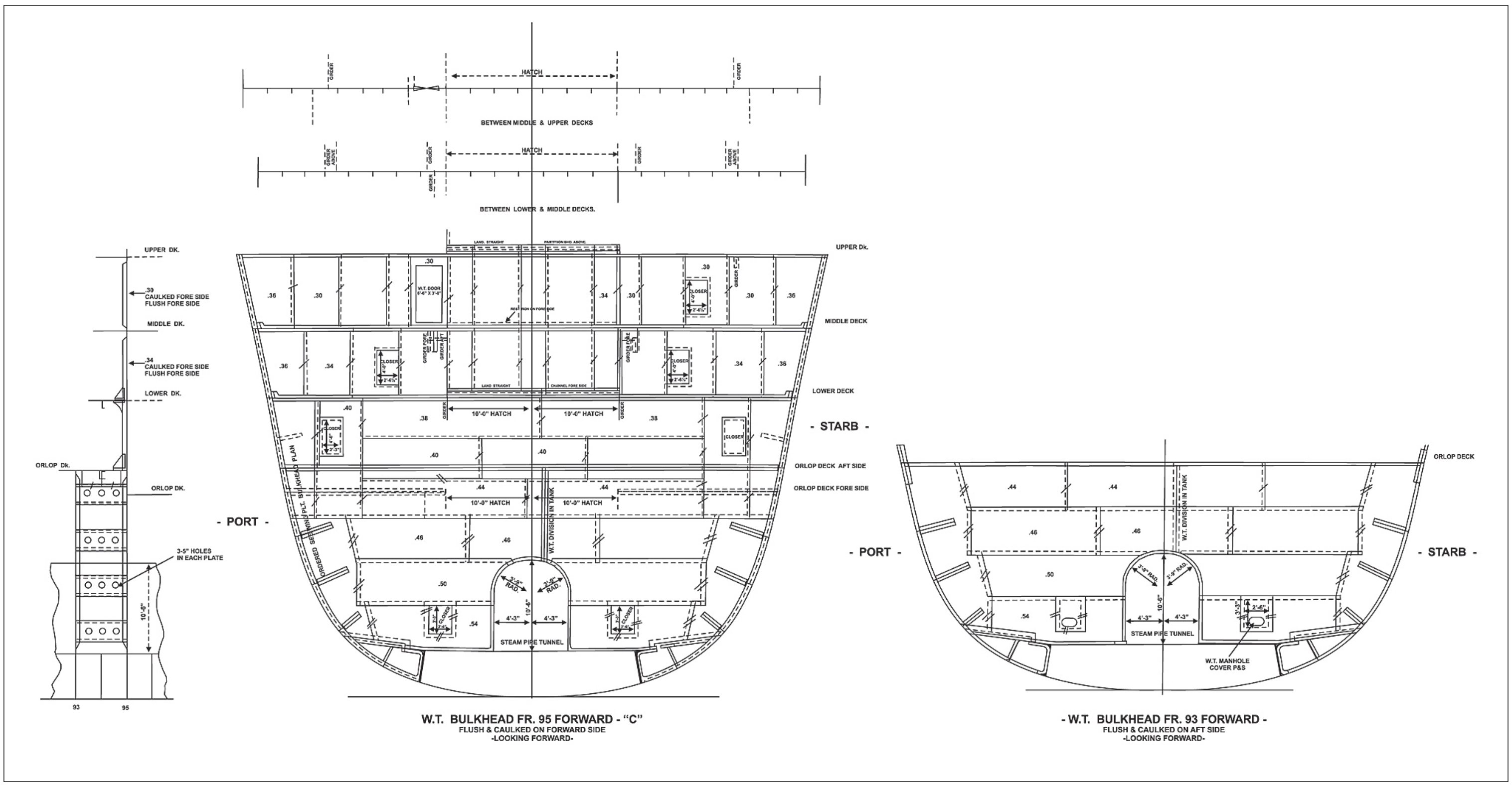
The first major transverse bulkhead aft of the bow, though not watertight, was the plating which enclosed the forward end of the chain locker, located above the Fore Peak Tank. This bulkhead was located forward of WTB A at frame 140F. Its bottom edge was riveted to the Orlop Deck with angles. (The Orlop Deck, which was caulked watertight, formed the top of the Fore Peak Tank.) The bulkhead extended vertically to the bottom of E Deck, after which it became the upper extension of WTB A, being made watertight between E and D Decks.

Watertight Bulkhead A

WTB A was the first watertight bulkhead aft of the bow, and was known as the ‘collision bulkhead’. It was located at frame 134F, where it extended up from the bottom of the hull to the underside of E Deck. The lower portion of this bulkhead formed the forward end of the foremost double-bottom tank, and the after bulkheads of both the Fore Peak Tank and the chain


2'-6" TRUNK
PARTITION BHD.
GIRDER
FRAME 111
-PLAN BETWEEN MIDDLE & UPPER DKS.-
BELOW LOWER DK.
FRAME 114
112 F.
11'-3"
-PLAN BETWEEN MIDDLE & LOWER DKS.-
FRAME 111
UPPER DK.
PLATING .30
MIDDLE DK.
PLATING .34
LOWER DK.
ORLOP DK.
PLTS .40
LOWER ORLOP DK.
2'-6"
111
112
114 FORD.
UPPER DECK
MIDDLE DECK
LOWER DECK
LOWER ORLOP DECK AFT SIDE
LOWER ORLOP DECK
- PORT -
- STARB. -
SEE WING PLATE BULKHEAD PLAN
GIRDERS
.30
.34
.38
.40
.44
.48
.50

W.T. BULKHEAD FR. 114 FORWARD - “B”
FLUSH & CAULKED ON AFT SIDE
-LOOKING FORWARD-


HATCH
BETWEEN MIDDLE & UPPER DECKS
HATCH
BETWEEN LOWER & MIDDLE DECKS.
UPPER DK.
.30 CAULKED FORE SIDE FLUSH FORE SIDE
MIDDLE DK.
.34 CAULKED FORE SIDE FLUSH FORE SIDE
LOWER DK.
ORLOP Dk.
ORLOP DK.
3-5" HOLES IN EACH PLATE
10'-6"
93
95
- PORT -
UPPER Dk.
MIDDLE DECK
LOWER DECK
- STARB -
ORLOP DECK AFT SIDE
ORLOP DECK FORE SIDE
10'-0" HATCH
STEAM PIPE TUNNEL
W.T. BULKHEAD FR. 95 FORWARD - "C"
FLUSH & CAULKED ON FORWARD SIDE
-LOOKING FORWARD-
ORLOP DECK
- PORT -
- STARB -
W.T. MANHOLE COVER P&S
STEAM PIPE TUNNEL
- W.T. BULKHEAD FR. 93 FORWARD -
FLUSH & CAULKED ON AFT SIDE
-LOOKING FORWARD-

locker. At E Deck, the bulkhead was stepped forward to frame 140F; between these two locations the deck was caulked for watertightness, creating a watertight flat. Though this watertight bulkhead was continued to the underside of C Deck as a structural element, it was only made watertight to the underside of D Deck. The length of this compartment measured 46ft to the forward perpendicular.

Watertight Bulkhead B

This was the second watertight bulkhead aft of the bow, located at frame 114F, where it extended up to the underside of G Deck. At G Deck the bulkhead was stepped aft horizontally to frame 111F, at which point it was extended to the underside of D Deck.[4] The compartment space measured 46ft 4in feet forward to WTB A at the hold level. WTB B formed the aft side of the No.1 Hold from the Tank Top to the bottom of G Deck. This bulkhead was also the point at which the watertight Firemen's Tunnel started, commencing aft.

Watertight Bulkhead C

This was the third watertight bulkhead aft of the stem, located at frame 95F. In addition to its primary purpose, this bulkhead was one of a pair of bulkheads which enclosed a fresh-water tank. The corresponding shorter bulkhead was located two frames aft at 93F. WTB C extended up to the under side of E Deck. The corresponding bulkhead, which formed the after end of the fresh-water tank, extended to the underside of the Orlop Deck. The compartment area of WTB C measured 50ft 6in feet forward to WTB B at the hold level and formed part of the after side of the No.2 Hold.

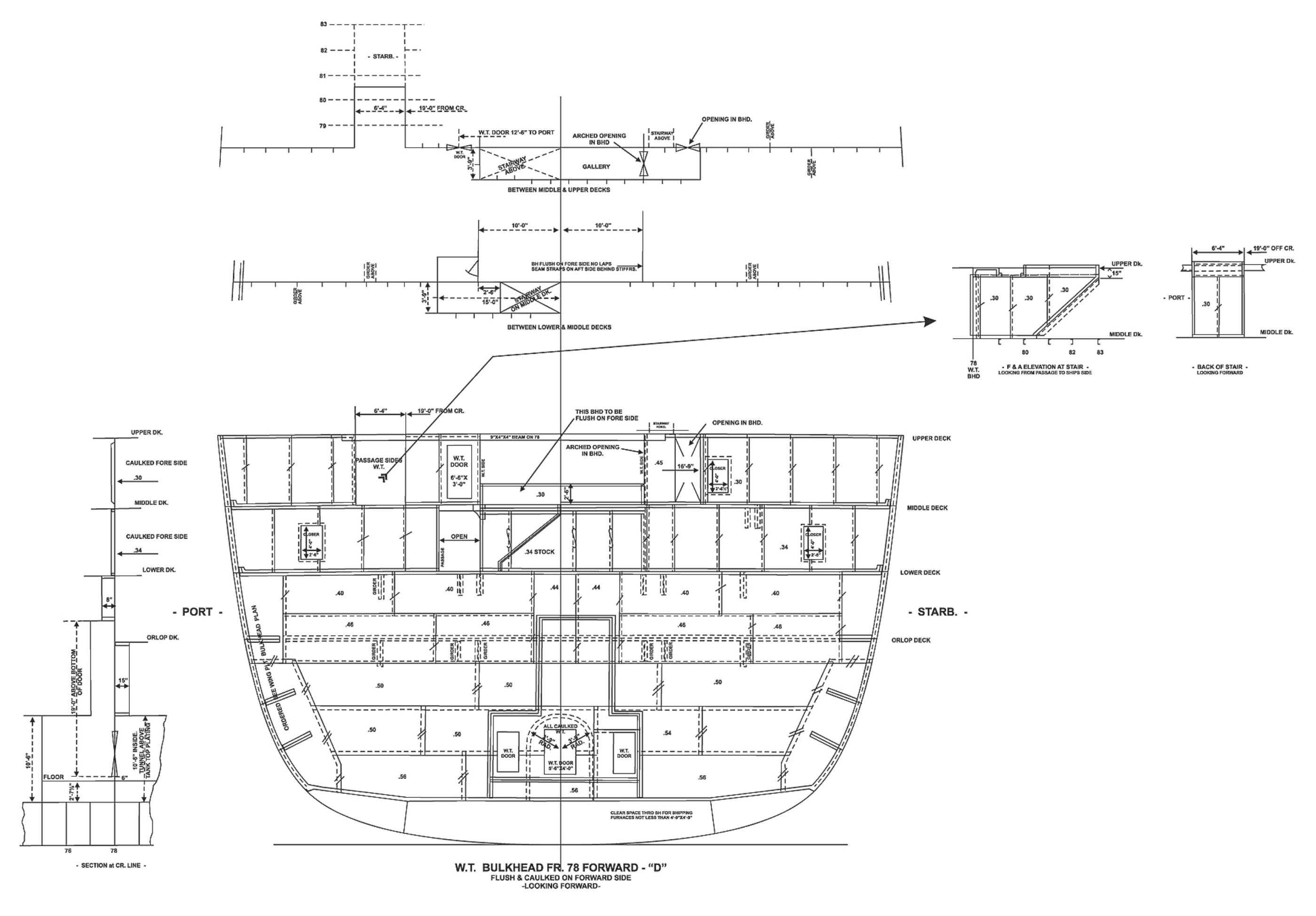
WTB C and the after bulkhead of the fresh-water tank were connected together by heavy horizontal steel girders 2ft 6in high; this water tank was sealed at the top by the Orlop Deck, which was caulked watertight. An arched opening for the Firemen's Tunnel, 10ft 6in high by 8ft 6in wide, was located at the Tank Top level on the centerline, extending through both bulkheads and the water tank.

Watertight Bulkhead D

This was the fourth watertight bulkhead aft of the bow, located at frame 78F and extended up to the underside of E Deck. The compartment space measured 51ft to WTB C, inclusive of the fresh-water tank at the forward end.

This bulkhead was located at the after end of the watertight Firemen's Tunnel, where it formed the forward side of a cofferdam which took the form of a small watertight vestibule. This small compartment was constructed in such a way as to incorporate a capped watertight vertical shaft, or 'trunk', within its roof to accommodate the tunnel's vertical-sliding watertight door and closing mechanism.

The vestibule extended aft to frame 75F and WTB D, where it was fitted with a second vertical-sliding watertight door providing access into No.6 Boiler Room. Within the forward bulkhead of the vestibule


BETWEEN MIDDLE & UPPER DECKS
W.T. DOOR 12'-6" TO PORT
ARCHED OPENING IN BHD
GALLERY
OPENING IN BHD.
BETWEEN LOWER & MIDDLE DECKS
BH FLUSH ON FORE SIDE NO LAPS SEAM STRAPS ON AFT SIDE BEHIND STIFFRS.
UPPER Dk.
MIDDLE Dk.
15"
78 W.T. BHD
80
82
83
- F & A ELEVATION AT STAIR -
LOOKING FROM PASSAGE TO SHIPS SIDE
6'-4"
19'-0" OFF CR.
- PORT -
- BACK OF STAIR -
LOOKING FORWARD
THIS BHD TO BE FLUSH ON FORE SIDE
PASSAGE SIDES W.T.
W.T. DOOR
UPPER DECK
MIDDLE DECK
LOWER DECK
ORLOP DECK
- PORT -
- STARB. -
.34 STOCK
ALL CAULKED W.T.
W.T. DOOR 5'-6"X4'-0"
CLEAR SPACE THRO BH FOR SHIPPING FURNACES NOT LESS THAN 4'-9"X4'-9"
UPPER DK.
CAULKED FORE SIDE
MIDDLE DK.
LOWER DK.
ORLOP DK.
FLOOR
78
- SECTION at CR. LINE -
W.T. BULKHEAD FR. 78 FORWARD - "D"
FLUSH & CAULKED ON FORWARD SIDE
-LOOKING FORWARD-

was a pair of vertically hinged watertight doors, one located to either side of the watertight door into the Firemen's Tunnel for accessing the No.3 Hold.

Watertight Bulkhead E

This was the fifth watertight bulkhead aft of the bow, located at frame 60F and extending up to the underside of E Deck. The compartment space measured 54ft to WTB D. WTB E formed the after end of the compartment containing No.6 Boiler Room and the forward end of the compartment containing No.5 Boiler Room. It divided the coal bunkers to the underside of F Deck and the boiler casing to the underside of E Deck, where it also provided structural support for the boiler uptakes of these two boiler rooms, and for the lower portions of the No.1 Funnel. At F Deck, it formed the forward wall of the Swimming Bath compartment on the starboard side, and the forward wall of the linen Drying Room on the port side.

Watertight Bulkhead F

This was the sixth watertight bulkhead aft of the bow, located at frame 41F and extending up to the underside of E Deck. The compartment space measured 57ft to WTB D. WTB F formed the after end of the compartment containing No.5 Boiler Room and the forward end of the compartment containing No.4 Boiler Room. It divided the coal bunkers to the underside of F Deck and divided the boiler casing to the underside of E Deck. At F Deck, it formed the forward wall of the Turkish Bath suite on the starboard side, and the after wall of the Linen Store on the port side.

Watertight Bulkhead G

This was the seventh watertight bulkhead aft of the bow, located at frame 22F and extending up to the underside of E Deck. The compartment space measured 57ft forward to WTB F. WTB G formed the after end of the compartment containing No.4 Boiler Room and forward end of the compartment containing No.3 Boiler Room. It divided the coal bunkers to the underside of F Deck and the boiler casing to the underside of E Deck, where it also provided structural support for the boiler uptakes of these two boiler rooms, and for the lower portions of the No.2 Funnel. At F Deck it formed the after walls of the Turkish Bath suite on the starboard side and Stewards' and Cooks' accommodations on the port side.

Watertight Bulkhead H

This was the eighth watertight bulkhead aft of the bow, located at frame 3F and extending up to the underside of E Deck. The compartment space measured 57ft forward to WTB G. WTB H formed the after end of the compartment containing No.3 Boiler Room and forward end of the compartment containing No.2 Boiler Room. It divided the coal bunkers to the underside of F Deck and the boiler casing to the underside of E Deck. It also divided the Third Class Dining Saloon on F Deck into two rooms.

Watertight Bulkhead J

This was the ninth watertight bulkhead aft of the bow, located at frame 18A and extending up to the underside of E Deck. The compartment space measured 60ft to WTB H. WTB J formed the after end of the compartment containing No.2 Boiler Room and forward end of the compartment containing No.1 Boiler Room. It divided the coal bunkers to the underside of F Deck and the boiler casing to the underside of E Deck, where it also provided structural support for the boiler uptakes of these two boiler rooms, and for the lower portions of the No.3 Funnel. It also formed the after wall of the port and starboard Third Class Pantries, the forward walls of the Third Class Galley on the starboard side and the Bakers' accommodations on the port side.

Watertight Bulkhead K

This was the tenth watertight bulkhead aft of the bow, located at frame 30A and extending up to the underside of D Deck. The compartment space measured 36ft to WTB J. WTB K formed the after bulkhead of No.1 Boiler Room and forward bulkhead of the Reciprocating Engine Room. It also separated the Third Class Galley complex on the starboard side and the Third Class Stewards' accommodation on the port side from the Engineers' accommodations on F Deck.

Watertight Bulkhead L

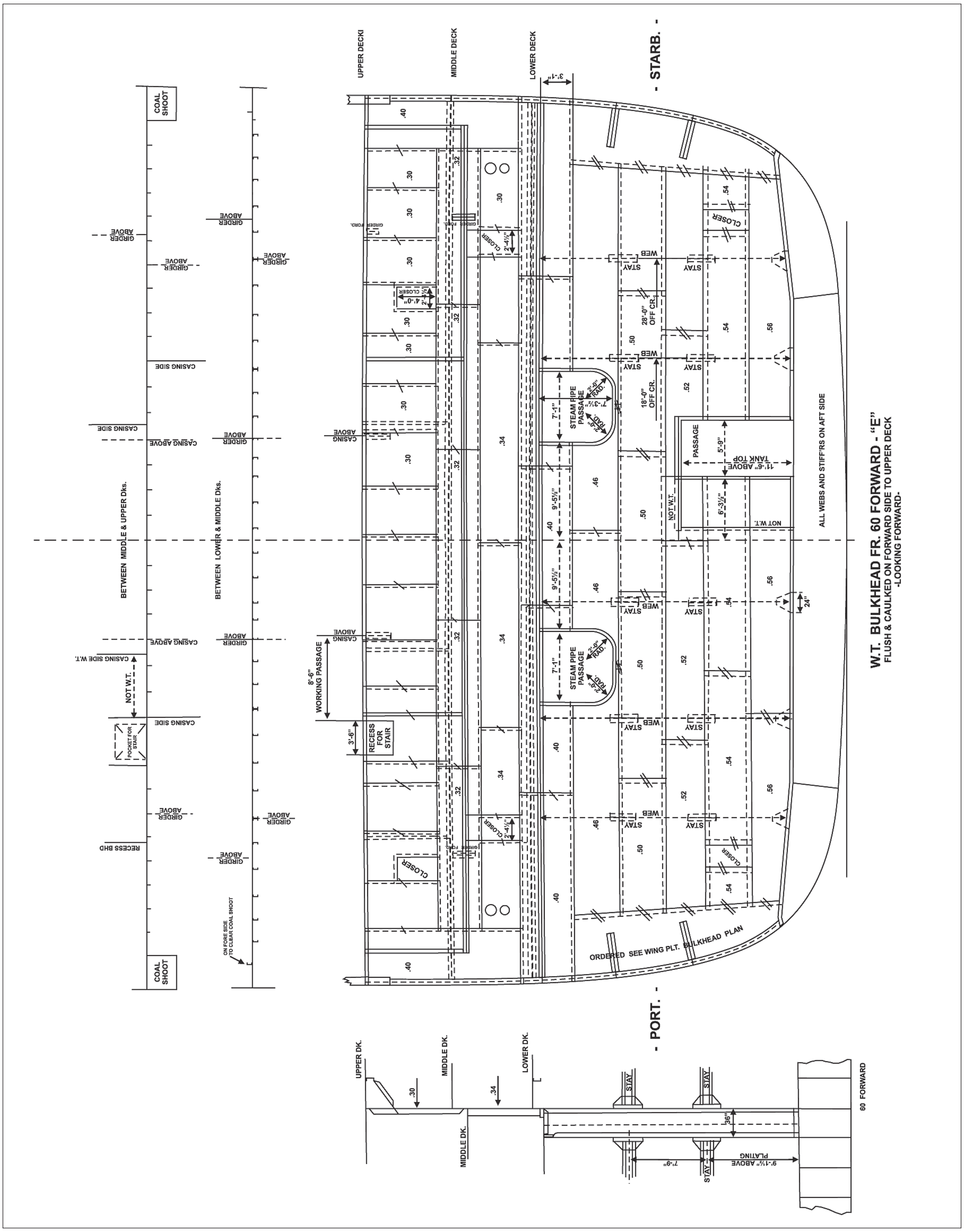
This was the eleventh watertight bulkhead aft of the bow, located at frame 58A. It extended up to the underside of D Deck and measured 69ft to WTB K. WTB L formed the after bulkhead of the Reciprocating Engine Room to the underside of D Deck, and the forward bulkhead of the Turbine Engine Room. On G Deck, WTB L separated the Engineers' Workshop on the starboard side and the oil tank flat and Brine Tank Room on the port side from the condenser discharge recesses; on F Deck it separated the Engineers' accommodations on either side of the reciprocating engine casing from the Second Class passenger accommodations immediately aft; and on E Deck it bisected the aftermost First Class passenger accommodations while on the port side it separated the Engineers' accommodations from those of the *à la carte* Restaurant staff. This was the first bulkhead through which the wing propeller shafts passed.

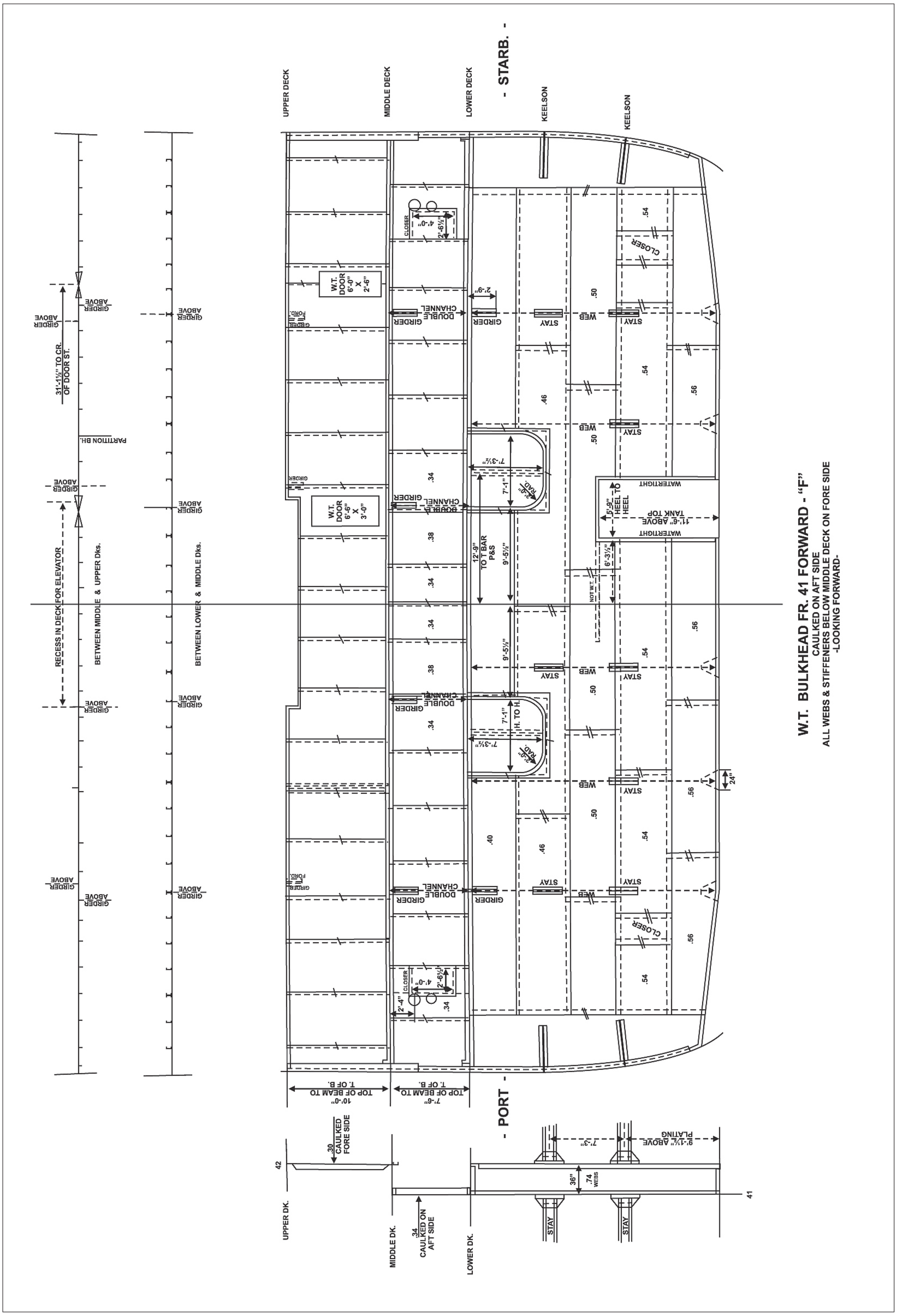
Watertight Bulkhead M

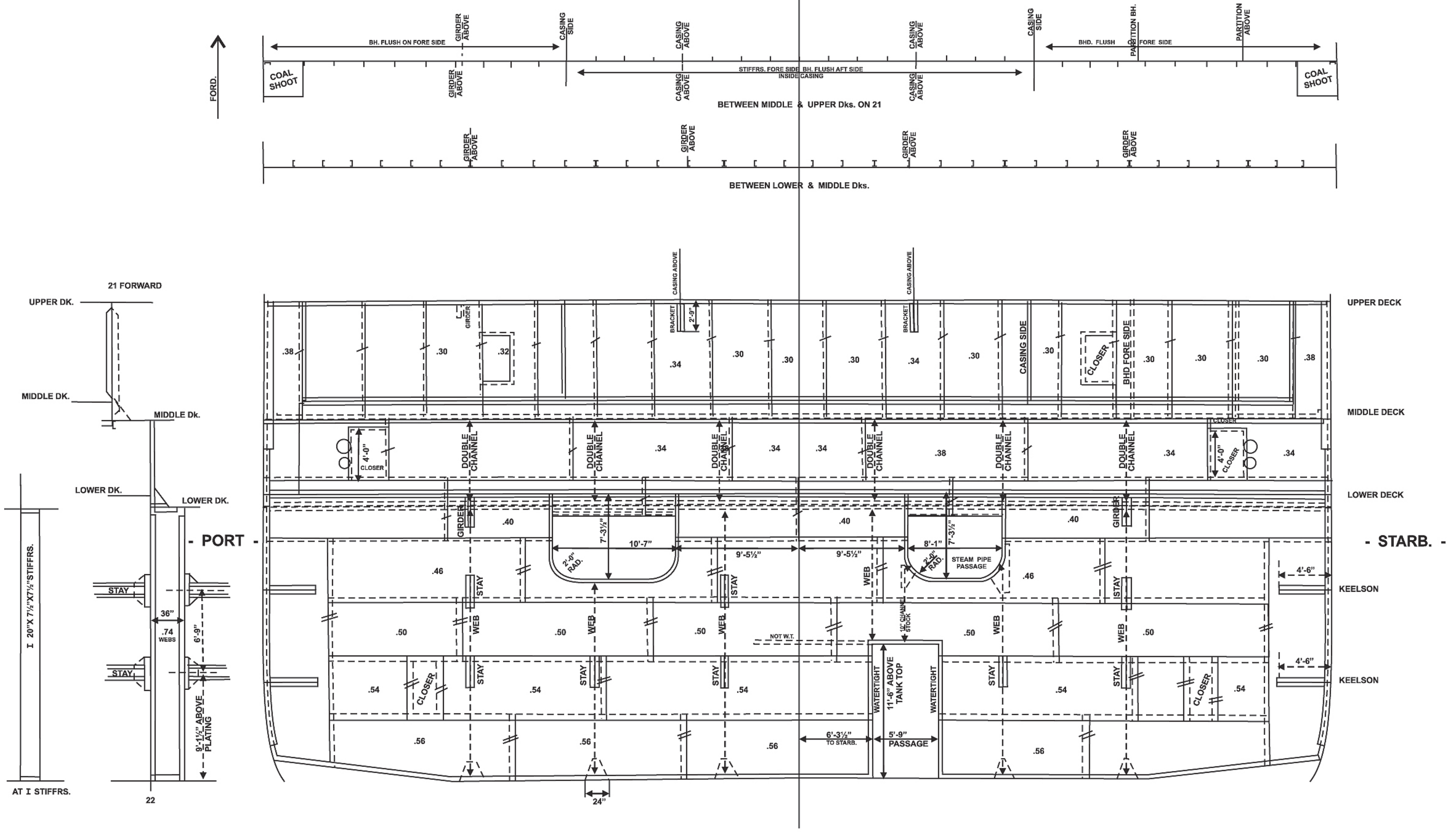
This was the twelfth watertight bulkhead aft of the bow, located at frame 71A. It extended up to the underside of D Deck and measured 54ft to WTB K, excluding the recess let into the bulkhead for the after rotor bearing seats and center shaft bulkhead gland. WTB M formed the after bulkhead of the Turbine Engine Room and forward bulkhead of the Electric Engine Room. On G Deck, WTB M was stepped forward parallel to the keel on both sides and formed much of the port and starboard casings of the Turbine Engine Room as well as the after bulkheads of both discharge recesses. The decks between the casing and shell were caulked watertight to form 'flats' which contained both uninsulated and insulated (refrigerated) store rooms for the galleys. WTB M separated the refrigerated stores area on the Orlop and G Decks from the Turbine Engine Room. On F Deck, it was the forward one of two bulkheads dividing the Second Class passenger accommodations into three separate areas. On E Deck, WTB M separated the First and Second Class passenger accommodations on the starboard side, while on the port side, it separated the accommodations of the *à la carte* Restaurant staff from those of Third Class passengers.

Watertight Bulkhead N

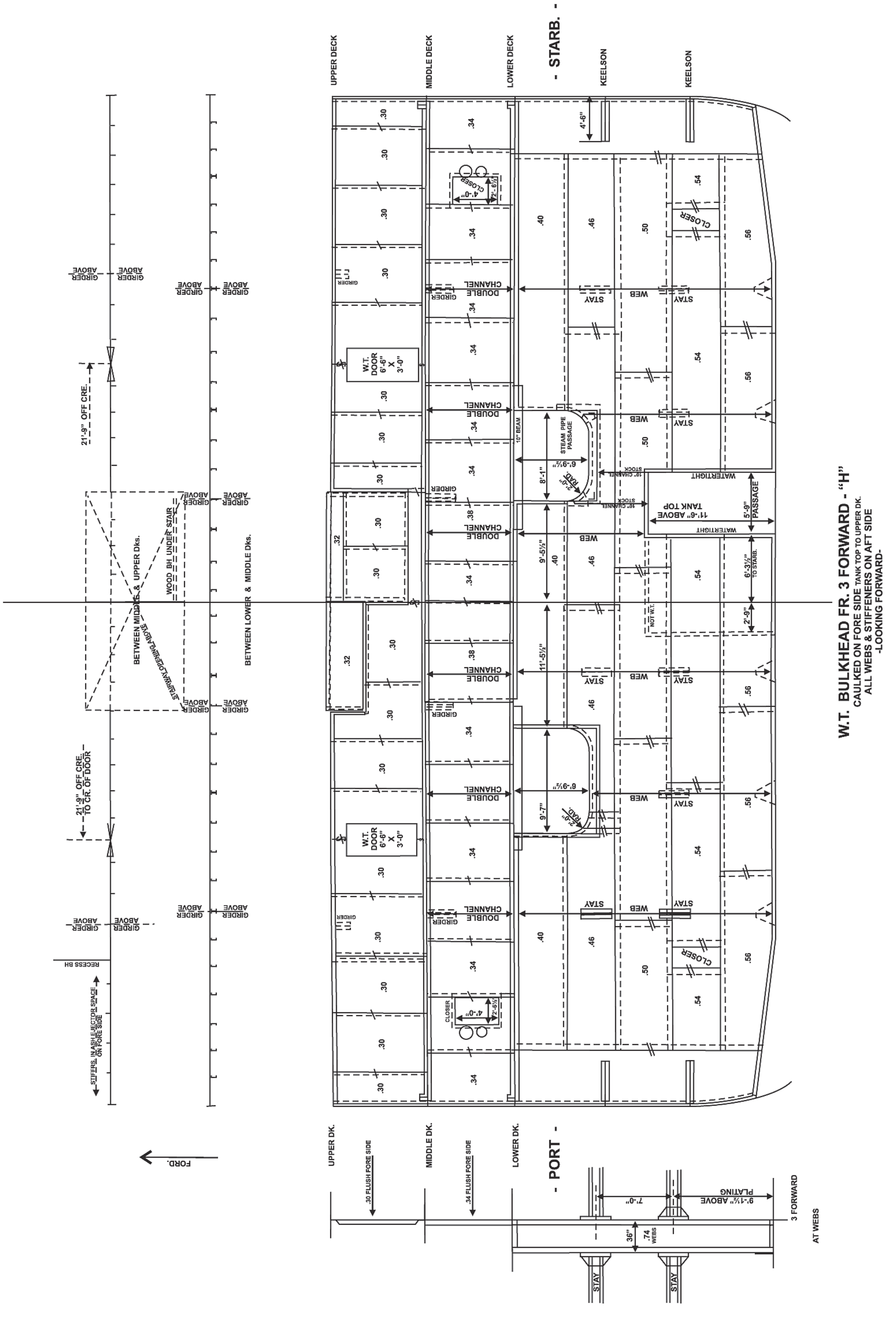
This was the thirteenth watertight bulkhead aft of the bow, located at frame 93A. It extended up to the underside of D Deck and measured 63ft to WTB M. WTB N formed the after bulkhead of the Electric Engine Room and the forward bulkhead of the forward Shaft Tunnel. It separated the ship's stores area from the refrigerated cargo hold on the aft side of the bulkhead, and on G Deck, it separated the refrigerated stores from the Third Class passenger accommodation. On F Deck, WTB N was the after one of two bulkheads dividing the Second Class passenger accommodation into three separate areas. On E Deck this bulkhead bisected the Second Class passenger accommodations on the starboard side, while on the port side it was the forward bulkhead of two dividing the Third Class passenger accommodations into three separate areas.

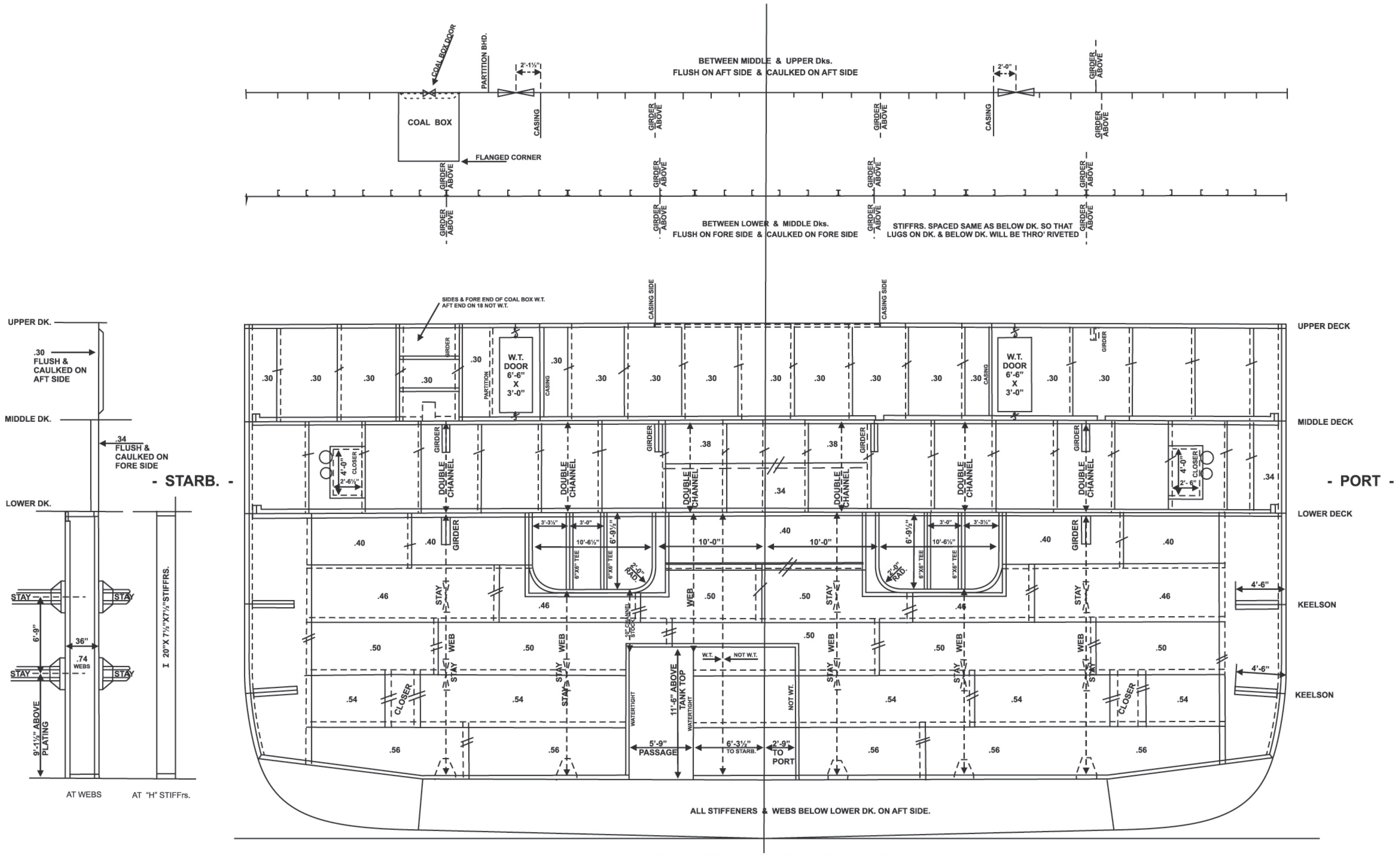

W.T. BULKHEAD FR. 60 FORWARD - "E"
FLUSH & CAULKED ON FORWARD SIDE TO UPPER DECK
-LOOKING FORWARD-
ALL WEBS AND STIFF'RS ON AFT SIDE
- STARB. -
- PORT. -
UPPER DECK
MIDDLE DECK
LOWER DECK
BETWEEN MIDDLE & UPPER Dks.
BETWEEN LOWER & MIDDLE Dks.
COAL SHOOT
GIRDER ABOVE
CASING SIDE
CASING ABOVE
CASING SIDE W.T.
NOT W.T.
POCKET FOR STAIR
RECESS BHD
ON FORE SIDE TO CLEAR COAL SHOOT
9'-6" WORKING PASSAGE
3'-6"
RECESS FOR STAIR
CLOSER
STEAM PIPE PASSAGE
7'-1"
9'-5½"
2'-0" RAD.
WEB
STAY
28'-0" OFF CR.
18'-0" OFF CR.
PASSAGE
5'-9"
11'-6" ABOVE TANK TOP
6'-3½"
NOT W.T.
24"
ORDERED SEE WING PLT. BULKHEAD PLAN
3'-1"
UPPER DK.
MIDDLE DK.
LOWER DK.
36"
7'-9"
9'-1½" ABOVE PLATING
60 FORWARD
.30
.32
.34
.40
.46
.50
.52
.54
.56


W.T. BULKHEAD FR. 41 FORWARD - "F"
CAULKED ON AFT SIDE
ALL WEBS & STIFFENERS BELOW MIDDLE DECK ON FORE SIDE
-LOOKING FORWARD-
- STARB. -
- PORT -
UPPER DECK
MIDDLE DECK
LOWER DECK
KEELSON
KEELSON
W.T. DOOR 6'-0" X 2'-6"
W.T. DOOR 6'-6" X 3'-0"
DOUBLE GIRDER CHANNEL
GIRDER
STAY
WEB
CLOSER
WATERTIGHT
TANK TOP 11'-6" ABOVE
HEEL TO HEEL 5'-9"
NOT W.T.
12'-9" TO T BAR P&S
9'-5½"
7'-1"
7'-3½"
H. TO H.
2'-9"
4'-0"
2'-6½"
2'-4"
24"
RECESS IN DECK FOR ELEVATOR
31'-1½" TO CR. OF DOOR ST.
PARTITION BH.
GIRDER ABOVE
BETWEEN MIDDLE & UPPER Dks.
BETWEEN LOWER & MIDDLE Dks.
10'-0" TOP OF BEAM TO T. OF B.
7'-6" TOP OF BEAM TO T. OF B.
UPPER DK.
MIDDLE DK.
LOWER DK.
42
30 CAULKED FORE SIDE
34 CAULKED ON AFT SIDE
36"
74 WEBS
STAY
9'-1½" ABOVE PLATING
7'-3"
41
.34
.38
.40
.46
.50
.54
.56

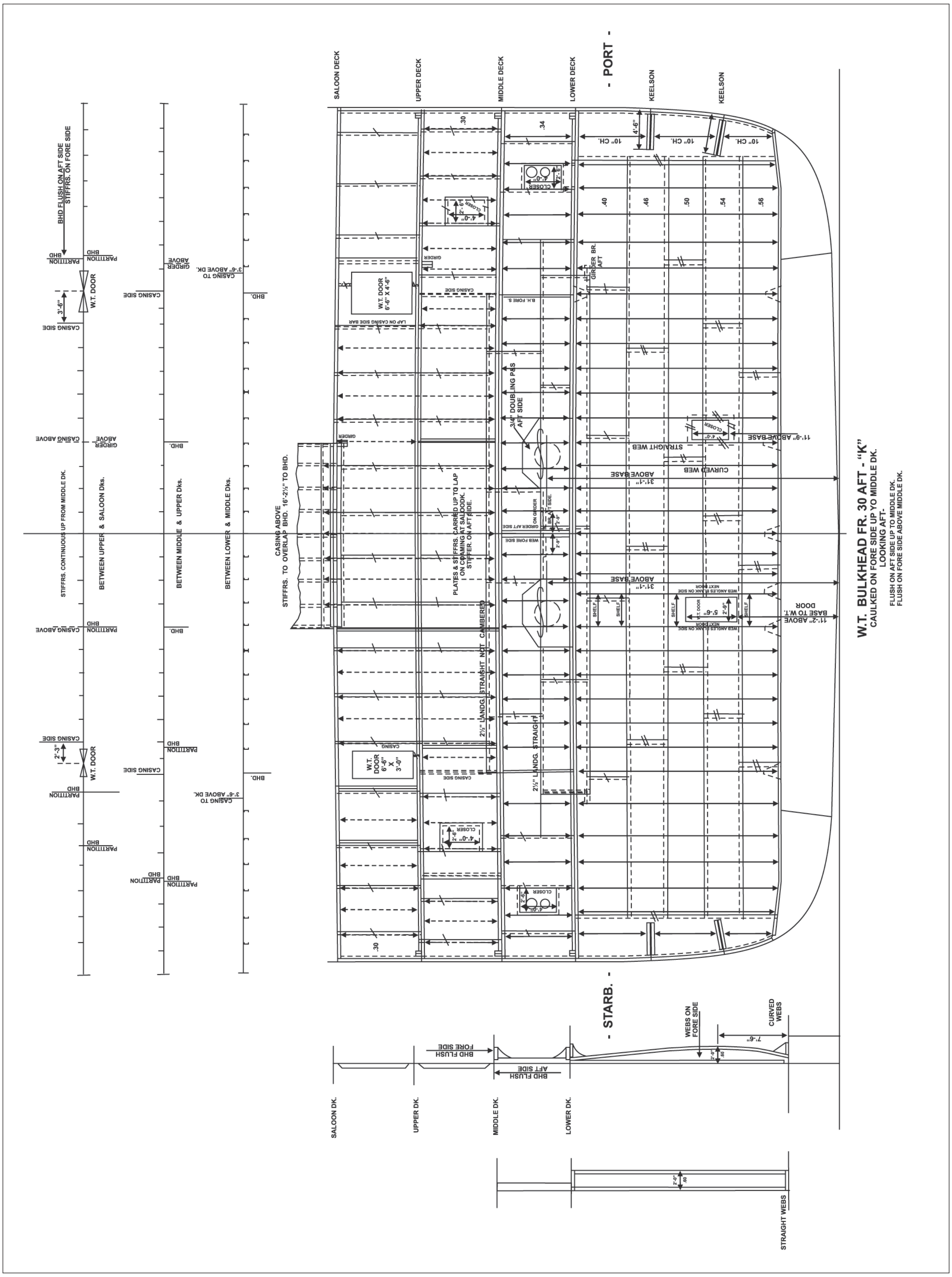

FORD.
COAL SHOOT
BH. FLUSH ON FORE SIDE
GIRDER ABOVE
CASING SIDE
CASING ABOVE
STIFFRS. FORE SIDE BH. FLUSH AFT SIDE INSIDE CASING
BHD. FLUSH
PARTITION BH. FORE SIDE
PARTITION ABOVE
BETWEEN MIDDLE & UPPER Dks. ON 21
BETWEEN LOWER & MIDDLE Dks.
CASING ABOVE
BRACKET
2'-9"
GIRDER
CLOSER
BHD FORE SIDE
UPPER DECK
MIDDLE DECK
LOWER DECK
DOUBLE CHANNEL
4'-0"
- PORT -
- STARB. -
.30
.32
.34
.38
.40
.46
.50
.54
.56
7'-3½"
10'-7"
2'-0" RAD.
9'-5½"
8'-1"
STEAM PIPE PASSAGE
4'-6"
KEELSON
STAY
WEB
NOT W.T.
12" CHANNEL STOCK
WATERTIGHT
11'-6" ABOVE TANK TOP
6'-3½" TO STARB.
5'-9" PASSAGE
24"
21 FORWARD
UPPER DK.
MIDDLE DK.
MIDDLE Dk.
LOWER DK.
I 20"X 7½"X7½"STIFFRS.
36"
.74 WEBS
6'-9"
9'-1½" ABOVE PLATING
AT I STIFFRS.
22

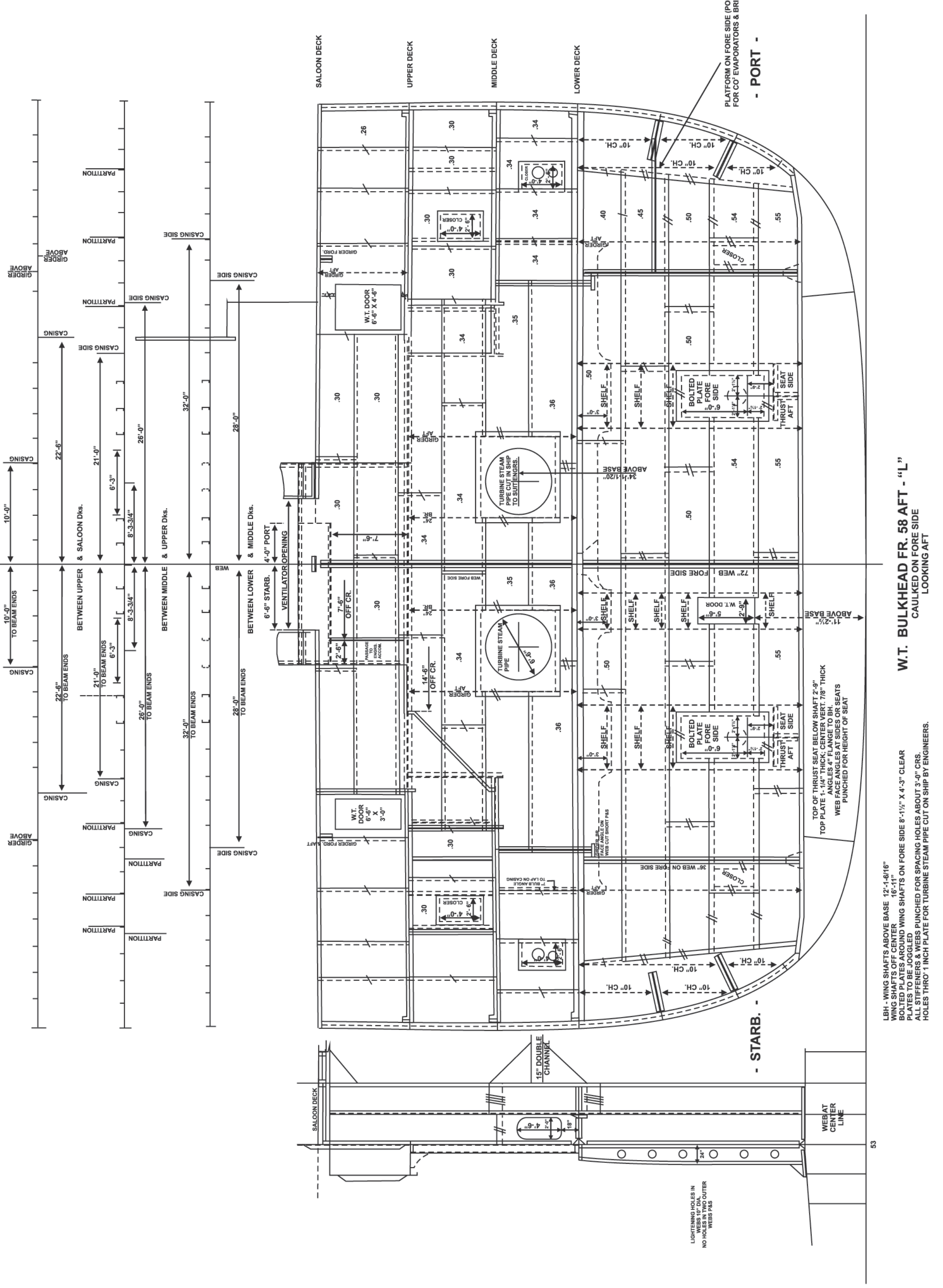
W.T. BULKHEAD FR. 22 FORWARD - "G"
CAULKED ON AFT SIDE
ALL WEBS & STIFFENERS BELOW MIDDLE DECK ON FORE SIDE
-LOOKING FORWARD-

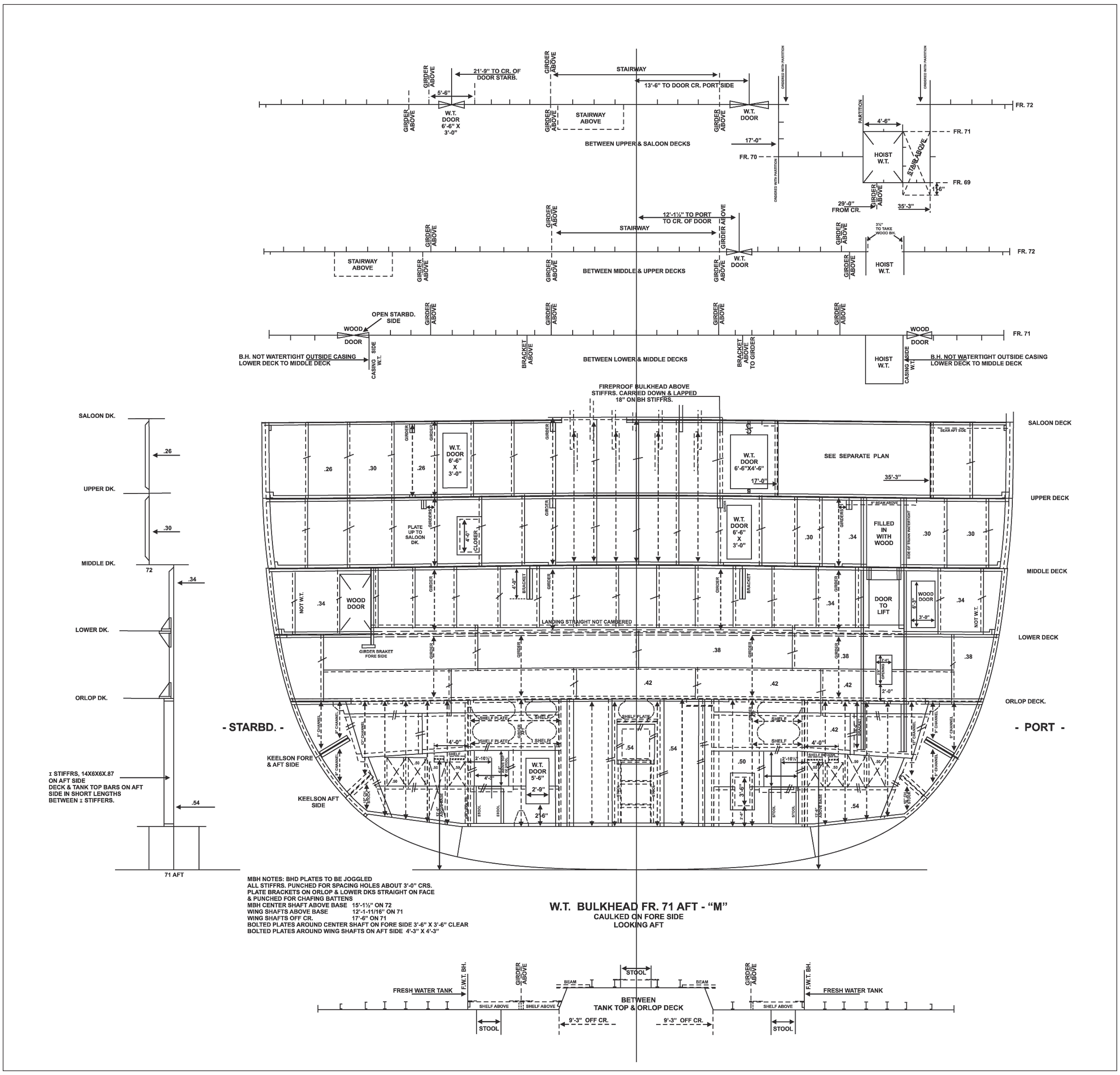

W.T. BULKHEAD FR. 3 FORWARD - "H"
CAULKED ON FORE SIDE TANK TOP TO UPPER DK.
ALL WEBS & STIFFENERS ON AFT SIDE
-LOOKING FORWARD-
UPPER DECK
MIDDLE DECK
LOWER DECK
- STARB. -
- PORT -
KEELSON
UPPER DK.
MIDDLE DK.
LOWER DK.
.30 FLUSH FORE SIDE
.34 FLUSH FORE SIDE
FORD.
W.T. DOOR 6'-6" X 3'-0"
DOUBLE CHANNEL
GIRDER
GIRDER ABOVE
CLOSER
STAY
WEB
STEAM PIPE PASSAGE
10" BEAM
TANK TOP 11'-6" ABOVE
WATERTIGHT
PASSAGE
5'-9"
6'-3½" TO STARB.
2'-9"
NOT W.T.
8'-1"
9'-5½"
11'-5½"
9'-7"
6'-9¾"
4'-6"
4'-0"
2'-6½"
21'-9" OFF CRE.
21'-9" OFF CRE. TO CR. OF DOOR
BETWEEN MIDDLE & UPPER Dks.
BETWEEN LOWER & MIDDLE Dks.
WOOD BH. UNDER STAIR
RECESS BH
STIFFS. IN ASH EJECTOR SPACE ON FORE SIDE
9'-1½" ABOVE PLATING
7'-0"
36"
.74 WEBS
3 FORWARD
AT WEBS
.30
.32
.34
.38
.40
.46
.50
.54
.56


BETWEEN MIDDLE & UPPER Dks.
FLUSH ON AFT SIDE & CAULKED ON AFT SIDE
BETWEEN LOWER & MIDDLE Dks.
FLUSH ON FORE SIDE & CAULKED ON FORE SIDE
STIFFRS. SPACED SAME AS BELOW DK. SO THAT LUGS ON DK. & BELOW DK. WILL BE THRO' RIVETED
COAL BOX DOOR
PARTITION BHD.
COAL BOX
FLANGED CORNER
CASING
GIRDER ABOVE
2'-1½"
2'-0"
SIDES & FORE END OF COAL BOX W.T. AFT END ON 18 NOT W.T.
CASING SIDE
UPPER DECK
MIDDLE DECK
LOWER DECK
KEELSON
- STARB. -
- PORT -
W.T. DOOR 6'-6" X 3'-0"
DOUBLE CHANNEL
GIRDER
CLOSER
STAY
WEB
10'-0"
10'-6½"
6'-9½"
6"X6" TEE
2'-0" RAD.
11'-6" ABOVE TANK TOP
WATERTIGHT
NOT WT.
W.T.
NOT W.T.
5'-9" PASSAGE
6'-3½" TO STARB.
2'-9" TO PORT
4'-6"
ALL STIFFENERS & WEBS BELOW LOWER DK. ON AFT SIDE.
UPPER DK.
.30 FLUSH & CAULKED ON AFT SIDE
MIDDLE DK.
.34 FLUSH & CAULKED ON FORE SIDE
LOWER DK.
I 20"X 7½"X7½"STIFFRS.
36"
.74 WEBS
6'-9"
9'-1½" ABOVE PLATING
AT WEBS
AT "H" STIFFrs.

W.T. BULKHEAD FR. 18 AFT - "J"
CAULKED ON FORE SIDE UP YO MIDDLE DK.
LOOKING AFT-


W.T. BULKHEAD FR. 30 AFT - "K"
CAULKED ON FORE SIDE UP YO MIDDLE DK.
LOOKING AFT.
FLUSH ON AFT SIDE UP TO MIDDLE DK.
FLUSH ON FORE SIDE ABOVE MIDDLE DK.
- PORT -
- STARB. -
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
KEELSON
KEELSON
10" CH.
10" CH.
10" CH.
4'-6"
.30
.34
.40
.46
.50
.54
.56
.30
GIRDER BR. AFT
STRAIGHT WEB
CURVED WEB
11'-9" ABOVE BASE
31'-1" ABOVE BASE
31'-1" ABOVE BASE
11'-2" ABOVE BASE TO W.T. DOOR
W.T. DOOR 5'-6" 2'-6"
SHELF
3/4" DOUBLING P&S AFT SIDE
PLATES & STIFFRS. CARRIED UP TO LAP ON COAMING AT SALOON DK. STIFFER. ON AFT SIDE.
CASING ABOVE
STIFFRS. TO OVERLAP BHD. 16'-2½" TO BHD.
2½" LANDG. STRAIGHT NOT CAMBERED
2½" LANDG. STRAIGHT
W.T. DOOR 6'-6" X 4'-6"
W.T. DOOR 6'-6" X 3'-0"
CLOSER 2'-6" 4'-0"
CASING SIDE
GIRDER
STIFFRS. CONTINUOUS UP FROM MIDDLE DK.
BETWEEN UPPER & SALOON Dks.
BETWEEN MIDDLE & UPPER Dks.
BETWEEN LOWER & MIDDLE Dks.
BHD FLUSH ON AFT SIDE STIFFRS. ON FORE SIDE
W.T. DOOR 3'-6"
W.T. DOOR 2'-3"
PARTITION BHD
CASING ABOVE
GIRDER ABOVE
CASING TO 3'-6" ABOVE DK.
BHD.
SALOON DK.
UPPER DK.
MIDDLE DK.
LOWER DK.
BHD FLUSH FORE SIDE
BHD FLUSH AFT SIDE
WEBS ON FORE SIDE
CURVED WEBS
7'-6"
2'-6" .60
STRAIGHT WEBS


W.T. BULKHEAD FR. 58 AFT - "L"
CAULKED ON FORE SIDE
LOOKING AFT
- PORT -
- STARB. -
PLATFORM ON FORE SIDE (PORT ONLY)
FOR CO² EVAPORATORS & BRINE PUMPS
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
BETWEEN UPPER & SALOON Dks.
BETWEEN MIDDLE & UPPER Dks.
BETWEEN LOWER & MIDDLE Dks.
CASING
CASING SIDE
PARTITION
GIRDER ABOVE
10'-0"
10'-0" TO BEAM ENDS
22'-6"
22'-6" TO BEAM ENDS
21'-0"
21'-0" TO BEAM ENDS
6'-3"
8'-3-3/4"
26'-0"
26'-0" TO BEAM ENDS
32'-0"
32'-0" TO BEAM ENDS
28'-0"
28'-0" TO BEAM ENDS
WEB
4'-0" PORT
6'-6" STARB.
VENTILATOR OPENING
W.T. DOOR 6'-6" X 4'-6"
W.T. DOOR 6'-6" X 3'-0"
7'-6" OFF CR.
14'-6" OFF CR.
TURBINE STEAM PIPE CUT IN SHIP TO SUIT ENGS.
TURBINE STEAM PIPE
34'-11/2" ABOVE BASE
11'-2½" ABOVE BASE
72" WEB FORE SIDE
36" WEB ON FORE SIDE
W.T. DOOR 5'-6" 2'-9"
SHELF
BOLTED PLATE FORE SIDE 6'-0"
THRUST SEAT AFT SIDE
CLOSER
10" CH.
.26
.30
.34
.35
.36
.40
.45
.50
.54
.55
TOP OF THRUST SEAT BELOW SHAFT 2'-9"
TOP PLATE 1-1/4" THICK; CENTER VERT. 7/8" THICK
ANGLES 4" FLANGE TO BH.
WEB FACE ANGLES AT SIDES OR SEATS
PUNCHED FOR HEIGHT OF SEAT
LBH - WING SHAFTS ABOVE BASE 12'-1-6/16"
WING SHAFTS OFF CENTER 16'-11"
BOLTED PLATES AROUND WING SHAFTS ON FORE SIDE 8'-1½" X 4'-3" CLEAR
PLATES TO BE JOGGLED
ALL STIFFENERS & WEBS PUNCHED FOR SPACING HOLES ABOUT 3'-0" CRS.
HOLES THRO' 1 INCH PLATE FOR TURBINE STEAM PIPE CUT ON SHIP BY ENGINEERS.
15" DOUBLE CHANNEL
SALOON DECK
WEB AT CENTER LINE
24"
18"
LIGHTENING HOLES IN WEBS 9" DIA. NO HOLES IN TWO OUTER WEBS P&S
53


GIRDER ABOVE
21'-9" TO CR. OF DOOR STARB.
STAIRWAY
13'-6" TO DOOR CR. PORT SIDE
W.T. DOOR 6'-6" X 3'-0"
STAIRWAY ABOVE
W.T. DOOR
BETWEEN UPPER & SALOON DECKS
FR. 72
FR. 71
FR. 70
FR. 69
HOIST W.T.
STAIR ABOVE
PARTITION
17'-0"
4'-6"
29'-0" FROM CR.
35'-3"
12'-1¼" TO PORT TO CR. OF DOOR
BETWEEN MIDDLE & UPPER DECKS
OPEN STARBD. SIDE
WOOD DOOR
B.H. NOT WATERTIGHT OUTSIDE CASING LOWER DECK TO MIDDLE DECK
CASING SIDE W.T.
BRACKET ABOVE
BETWEEN LOWER & MIDDLE DECKS
BRACKET ABOVE TO GIRDER
FIREPROOF BULKHEAD ABOVE STIFFRS. CARRIED DOWN & LAPPED 18" ON BH STIFFRS.
SALOON DK.
UPPER DK.
MIDDLE DK.
LOWER DK.
ORLOP DK.
72
.26
.30
.34
.54
ɪ STIFFRS, 14X6X6X.87 ON AFT SIDE
DECK & TANK TOP BARS ON AFT SIDE IN SHORT LENGTHS BETWEEN ɪ STIFFERS.
71 AFT
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
ORLOP DECK.
W.T. DOOR 6'-6"X4'-6"
SEE SEPARATE PLAN
PLATE UP TO SALOON DK.
CLOSER
FILLED IN WITH WOOD
NOT W.T.
DOOR TO LIFT
LANDING STRAIGHT NOT CAMBERED
GIRDER BRAKET FORE SIDE
.38
.42
- STARBD. -
- PORT -
KEELSON FORE & AFT SIDE
KEELSON AFT SIDE
SHELF PLATE
SHELF
W.T. DOOR 5'-6"
2'-9"
2'-6"
STOOL
MBH NOTES: BHD PLATES TO BE JOGGLED
ALL STIFFRS. PUNCHED FOR SPACING HOLES ABOUT 3'-0" CRS.
PLATE BRACKETS ON ORLOP & LOWER DKS STRAIGHT ON FACE
& PUNCHED FOR CHAFING BATTENS
MBH CENTER SHAFT ABOVE BASE 15'-1½" ON 72
WING SHAFTS ABOVE BASE 12'-1-11/16" ON 71
WING SHAFTS OFF CR. 17'-6" ON 71
BOLTED PLATES AROUND CENTER SHAFT ON FORE SIDE 3'-6" X 3'-6" CLEAR
BOLTED PLATES AROUND WING SHAFTS ON AFT SIDE 4'-3" X 4'-3"
W.T. BULKHEAD FR. 71 AFT - "M"
CAULKED ON FORE SIDE
LOOKING AFT
FRESH WATER TANK
F.W.T. BH.
SHELF ABOVE
BEAM
BETWEEN TANK TOP & ORLOP DECK
9'-3" OFF CR.

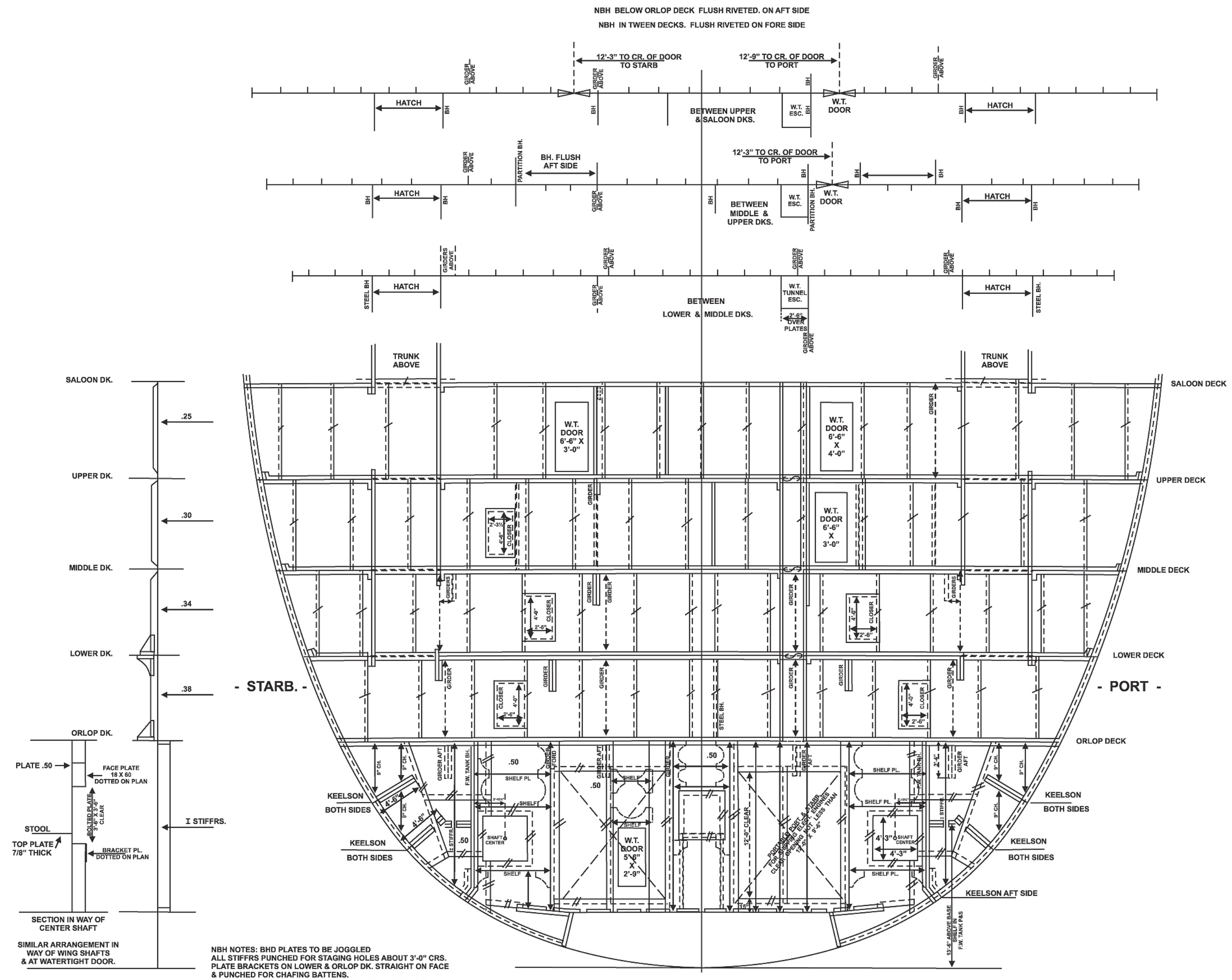
Watertight Bulkhead O

This was the fourteenth watertight bulkhead aft of the bow, located at frame 111A, and extending up to the underside of D Deck. The compartment measured 54ft to WTB N. WTB O subdivided the shaft tunnel into two compartments. It divided the refrigerated cargo hold from the general cargo hold beneath the No.6 Hatch on the Orlop Deck. On G Deck, WTB O bisected the Third Class accommodations, while on F Deck it separated the aftermost Second Class accommodations from those of Third Class. On E Deck it separated the Second Class accommodations on the starboard side from those of Third Class aft, while on the port side it was the after bulkhead of two dividing the Third Class passenger accommodations into three separate areas.

Watertight Bulkhead P

This was the fifteenth watertight bulkhead aft of the bow. The compartment space measured 57ft 6in to WTB O at the tunnel and hold levels. WTB P formed the after bulkhead of the shaft tunnels, and was also the forward bulkhead of the After Peak Tank. WTB P was located at frame 133A, where it extended up from the Tank Top to the underside of G Deck. At G Deck, WTB P was stepped aft horizontally to frame 139A, forming part of the watertight flat above the After Peak Tank. At frame

NBH BELOW ORLOP DECK FLUSH RIVETED. ON AFT SIDE
NBH IN TWEEN DECKS. FLUSH RIVETED ON FORE SIDE


12'-3" TO CR. OF DOOR TO STARB
12'-9" TO CR. OF DOOR TO PORT
GIRDER ABOVE
HATCH
BH
W.T. ESC.
W.T. DOOR
BETWEEN UPPER & SALOON DKS.
BH. FLUSH AFT SIDE
PARTITION BH.
12'-3" TO CR. OF DOOR TO PORT
BETWEEN MIDDLE & UPPER DKS.
STEEL BH.
GIRDERS ABOVE
W.T. TUNNEL ESC.
2'-6" OVER PLATES
BETWEEN LOWER & MIDDLE DKS.
TRUNK ABOVE
SALOON DK.
UPPER DK.
MIDDLE DK.
LOWER DK.
ORLOP DK.
.25
.30
.34
.38
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
ORLOP DECK
W.T. DOOR 6'-6" X 3'-0"
W.T. DOOR 6'-6" X 4'-0"
W.T. DOOR 6'-6" X 3'-0"
CLOSER
GIRDER
- STARB. -
- PORT -
PLATE .50
FACE PLATE 18 X 60 DOTTED ON PLAN
BOLTED PLATE 3'-6" X 3'-6" CLEAR
STOOL
TOP PLATE 7/8" THICK
BRACKET PL. DOTTED ON PLAN
I STIFFRS.
SECTION IN WAY OF CENTER SHAFT
SIMILAR ARRANGEMENT IN WAY OF WING SHAFTS & AT WATERTIGHT DOOR.
KEELSON BOTH SIDES
KEELSON AFT SIDE
SHAFT CENTER
SHELF PL.
SHELF
.50
W.T. DOOR 5'-6" X 2'-9"
12'-0" CLEAR
PORTABLE FOR SHIPPING CLEAR OPENING 12'-0" X 9'-6"
4'-3"
F.W. TANK BH.
13'-6" ABOVE BASE SHELF IN F.W. TANK F&S

NBH NOTES: BHD PLATES TO BE JOGGLED
ALL STIFFRS PUNCHED FOR STAGING HOLES ABOUT 3'-0" CRS.
PLATE BRACKETS ON LOWER & ORLOP DK. STRAIGHT ON FACE
& PUNCHED FOR CHAFING BATTENS.
BRACKETS UNDER LOWER DK. HOLLOWED OUT ON FACE.
NBH CR. SHAFT ABOVE BASE 14'-2-3/4"
NBH WING SHAFTS ABOVE BASE 12'-2-3/16"
NBH WING SHAFTS OFF CR. 18'-2'5/8"
BOLTED PLATE AROUND CR. SHAFT FITTED ON FORE SIDE CLEAR OPENING 3'-6" X 3'-6"
BOLTED PLATES AROUND WING SHAFTS FITTED ON AFT SIDE CLEAR OPENING 4'-3" X 4'-3"
CLEAR SPACE FOR SHIPPING ELECTRIC ENGINES THRO' BH NO LESS THAN 9'-6" X 12'-0" HIGH
WATERTIGHT DOORS IN 'TWEEN DKS 4" ABOVE TOP OF DK. BARS

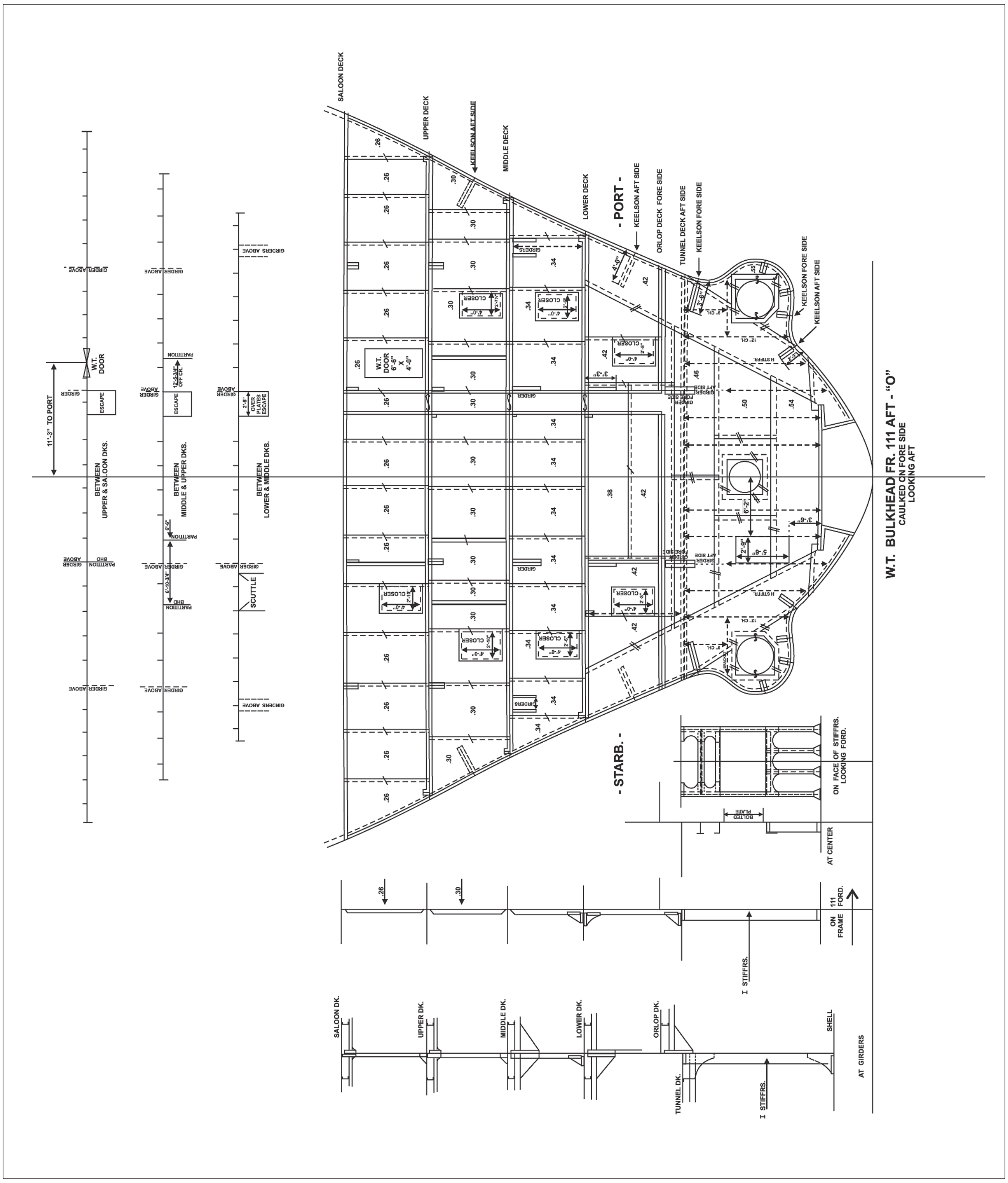
W.T. BULKHEAD FR. 93 AFT - "N"
CAULKED ON AFT SIDE BELOW ORLOP DECK
CAULKED ON FORE SIDE ORLOP DECK TO SALOON DECK
LOOKING AFT

139A, WTB P was extended vertically to the underside of D Deck. The space between WTB P and the sternpost was taken up by the After Peak Tank up to the underside of G Deck, and a store space up to the underside of E Deck. This area was the sixteenth watertight compartment.

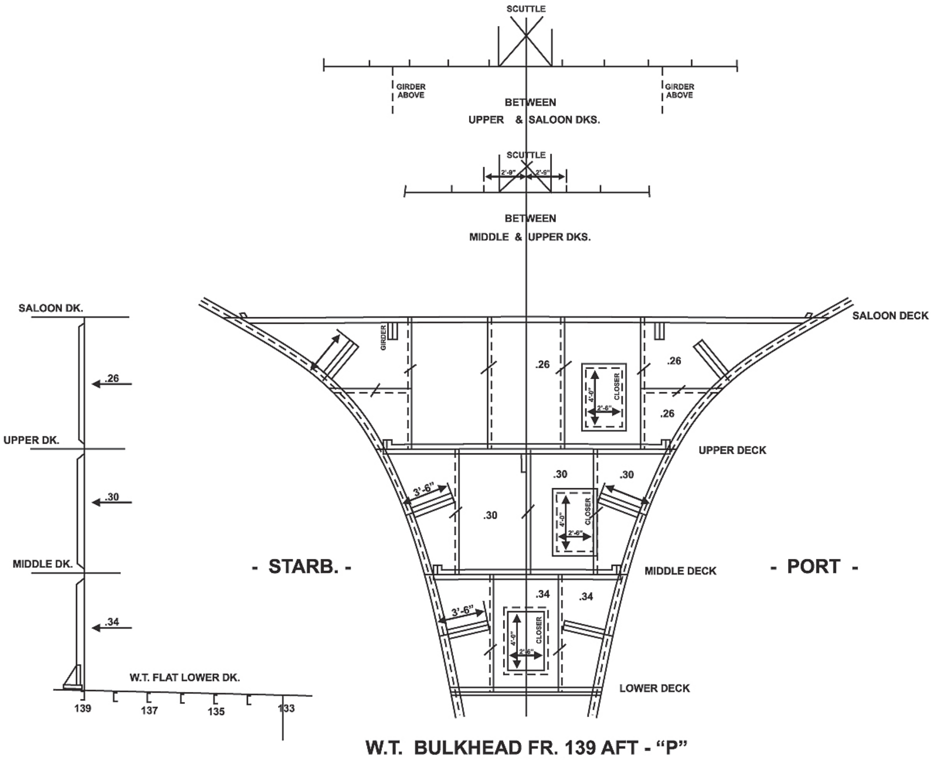
Watertight Bulkheads E through O inclusive each had a vertical-sliding watertight door fitted at the level of the deck plates of the boiler and machinery spaces for the use of the Engineers and Firemen; at WTB D there were, in effect, two vertical-sliding doors, with one located at each end of the vestibule at the forward entrance to No.6 Boiler Room. All of these doors were remotely operable from the Navigating Bridge. On the Orlop Deck, there was one door of the lateral-sliding type located on the forward side of WTB N for access to the refrigerated hold; an insulated, non-watertight vertically hinged door was fitted opposite this watertight door on the after side of the bulkhead within the refrigerated hold. On G Deck, there were no watertight doors in the bulkheads. All watertight doors on F Deck and above were of the manually operated, lateral-sliding type.

Coal bunker bulkheads

Within each boiler room were two transverse cross-bunkers, one to supply the forward furnaces and one to supply the after furnaces, the exception being No.1


W.T. BULKHEAD FR. 111 AFT - "O"
CAULKED ON FORE SIDE
LOOKING AFT
- PORT -
- STARB. -
SALOON DECK
UPPER DECK
KEELSON AFT SIDE
MIDDLE DECK
LOWER DECK
KEELSON AFT SIDE
ORLOP DECK FORE SIDE
TUNNEL DECK AFT SIDE
KEELSON FORE SIDE
KEELSON FORE SIDE
KEELSON AFT SIDE
W.T. DOOR 6'-6" X 4'-0"
CLOSER
BETWEEN UPPER & SALOON DKS.
BETWEEN MIDDLE & UPPER DKS.
BETWEEN LOWER & MIDDLE DKS.
11'-3" TO PORT
W.T. DOOR
ESCAPE
SCUTTLE
GIRDER ABOVE
PARTITION
ON FACE OF STIFFRS. LOOKING FORD.
AT CENTER
ON FRAME 111 FORD.
I STIFFRS.
SALOON DK.
UPPER DK.
MIDDLE DK.
LOWER DK.
ORLOP DK.
TUNNEL DK.
SHELL
AT GIRDERS

Boiler Room which had single-ended boilers only. The ends of the cross-bunkers were formed by transverse steel bulkheads located a distance of between 9ft and 13ft 6in to either side of the watertight bulkheads dividing the boiler rooms. The bunker bulkheads were lettered from 'P', located in the forward end of No.6 Boiler Room at frame 75F, and continuing aft to bunker bulkhead 'Z', located within No.1 Boiler Room at frame 22A. All bunker bulkheads aft of 'P' were pierced by horizontally-trunked steam pipe passages port and starboard beneath the G Deck level. A recess was worked into each of the after bunker bulkheads to provide space for the ash ejectors, while a dust-tight compartment was built within each after bunker, off to one side of the access tunnel between boiler rooms, to enclose and protect the ballast and ash ejector pumps and the valve manifolds for the ballast and bilge piping systems.


SCUTTLE
GIRDER ABOVE
GIRDER ABOVE
BETWEEN
UPPER & SALOON DKS.
SCUTTLE
BETWEEN
MIDDLE & UPPER DKS.
SALOON DK.
.26
UPPER DK.
.30
MIDDLE DK.
.34
W.T. FLAT LOWER DK.
139
137
135
133
SALOON DECK
GIRDER
.26
.26
.26
CLOSER
UPPER DECK
3'-6"
.30
.30
.30
CLOSER
- STARB. -
MIDDLE DECK
- PORT -
3'-6"
.34
.34
CLOSER
LOWER DECK

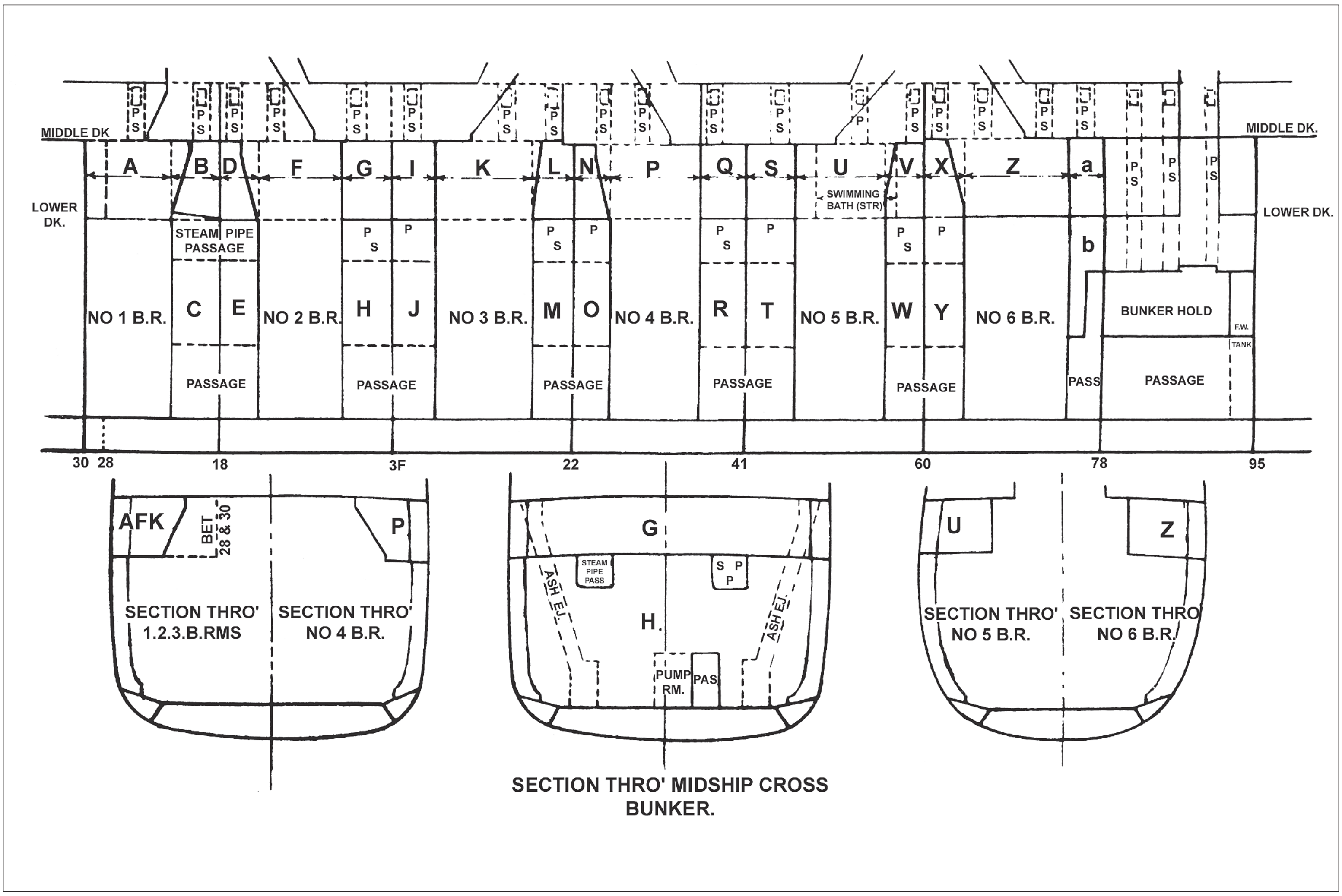
W.T. BULKHEAD FR. 139 AFT - "P"
CAULKED ON FORE SIDE
LOOKING AFT

The coal bunker bulkheads were plated horizontally with joggled plates which were terminated and connected to the sides of the ship through vertically oriented margin plates in much the same manner as the watertight bulkheads. The bottom strakes of the plating in way of the stokeholds were of increased thickness to avoid corrosion by ashes. The plating was stiffened with channels below the Lower Deck (G) and with bulb angles between the Lower (G) and the Middle (F) Decks. All stiffeners were placed on the bunker side of the plating.

The athwartship bunker bulkheads were stayed to the main watertight bulkheads at intervals by means of 15in web girders attached to deep I-bars on the bunker bulkheads. There were two of these connecting girders between the Tank Top and Lower Deck (G) being spaced about 10ft 6in apart athwartships.

To provide coal to the furnaces, a bunker door was located immediately opposite each of the firing stations, there being five per stokehold. Each bunker door had a clear opening of 2ft 9in x 5ft 0in, and was fitted with a counterbalanced, vertical-sliding steel-plate door. The openings were cut into the bulkhead plating at a height which placed the thresholds flush with the stokehold deck plates, the top of which were 2ft 7½in above the Tank Top plates.

In addition to containing five bunker doors, the bunker bulkheads at the forward end of each boiler room contained the 5ft 6in x 4ft 0in opening over which was installed the vertical-sliding watertight door providing access to the next compartment forward. The plating immediately surrounding each watertight door which formed the after end of the watertight passageway leading through the cross-bunkers was made thicker than that of the surrounding bunker plating. It was made to the same thickness as the watertight bulkhead to which it was connected, and was caulked watertight. The rest of the plating of the bunker bulkheads, as well as that of the casings and decks of the machinery spaces in the way of the passenger and crew accommodations, was made dust-tight.


MIDDLE DK
MIDDLE DK.
LOWER DK.
LOWER DK.
P S
A
B
D
F
G
I
K
L
N
P
Q
S
U
V
X
Z
a
b
SWIMMING BATH (STR)
STEAM PIPE PASSAGE
C
E
H
J
M
O
R
T
W
Y
NO 1 B.R.
NO 2 B.R.
NO 3 B.R.
NO 4 B.R.
NO 5 B.R.
NO 6 B.R.
BUNKER HOLD
F.W. TANK
PASSAGE
PASS
30
28
18
3F
22
41
60
78
95
AFK
BET 28 & 30
SECTION THRO' 1.2.3.B.RMS
SECTION THRO' NO 4 B.R.
STEAM PIPE PASS
S P P
ASH EJ.
PUMP RM.
PAS
SECTION THRO' NO 5 B.R.
SECTION THRO' NO 6 B.R.
SECTION THRO' MIDSHIP CROSS BUNKER.

BUNKER CAPACITIES

A PORT	50	**O**	325
A STAR	50	**P** PORT	58
B	159	**P** STAR	57
C	469	**Q**	142
D	118	**R**	435
E	328	**S**	140
F PORT	65	**T**	395
F STAR	64	**U** PORT	104
G	196	**U** STAR	20
H	543	**V**	104
I	128	**W**	365
J	340	**X**	102
K PORT	64	**Y**	307
K STAR	65	**Z** PORT	142
L	140	**Z** STAR	143
M	443	**a**	108
N	113	**b**	329

TOTAL 6611 TONS

BUNKER HOLD 1092 TONS
COAL TAKEN AT 44 CUB.FT. PER TON

Fig. 6-17 **Coal Bunker Arrangement** – This inboard profile and sections show the general layout of the coal bunkers of *Olympic* and *Titanic*. *(Illustration by Bruce Beveridge based on a diagram from an original* Olympic *specification book)*

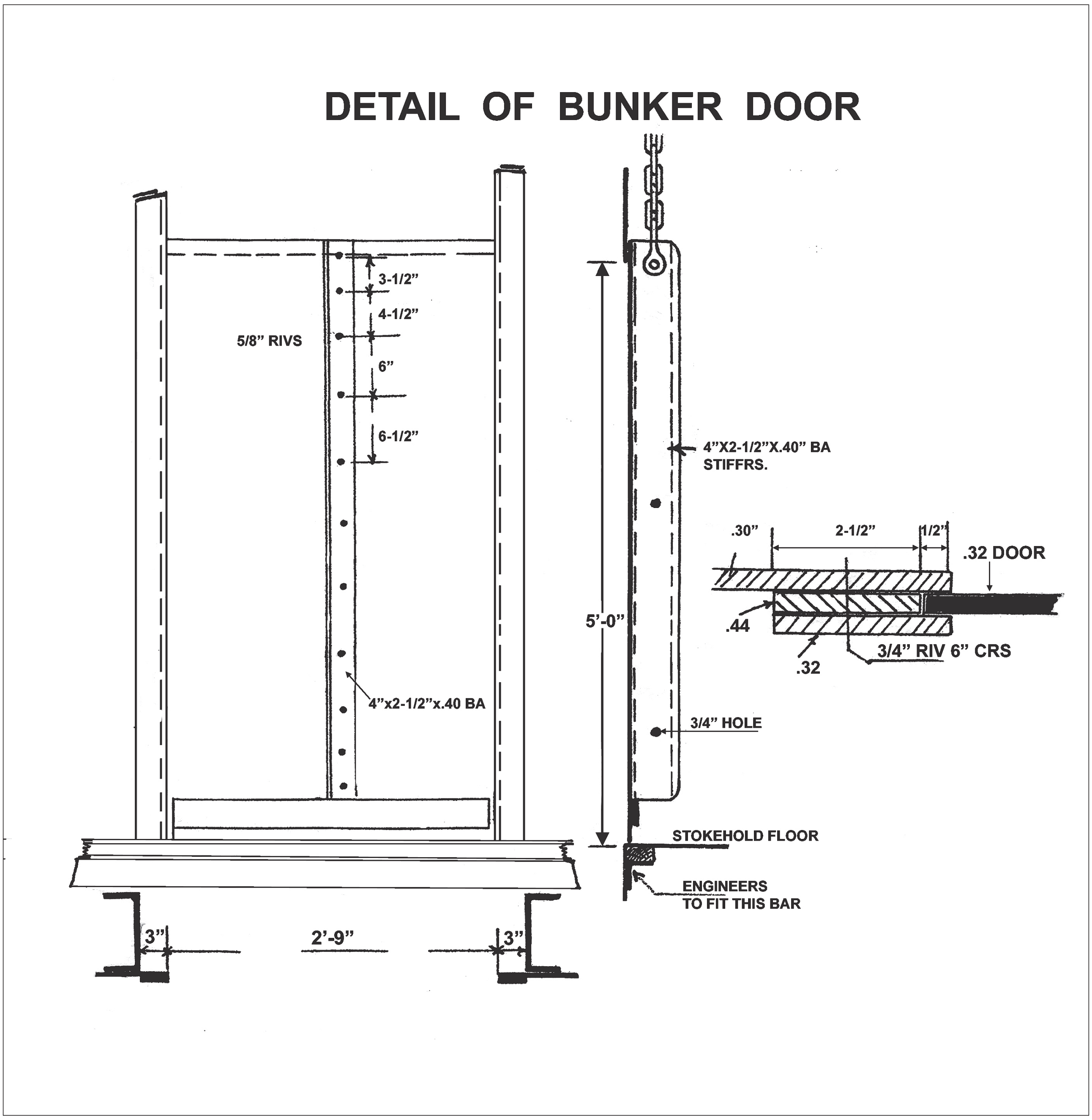

DETAIL OF BUNKER DOOR
3-1/2"
4-1/2"
5/8" RIVS
6"
6-1/2"
4"X2-1/2"X.40" BA
STIFFRS.
.30"
2-1/2"
1/2"
.32 DOOR
.44
.32
3/4" RIV 6" CRS
5'-0"
4"x2-1/2"x.40 BA
3/4" HOLE
STOKEHOLD FLOOR
ENGINEERS
TO FIT THIS BAR
3"
2'-9"
3"

Fig. 6-18 **Detail of Bunker Door**. *(Illustration by Bruce Beveridge based on original H&W bunker drawings)*

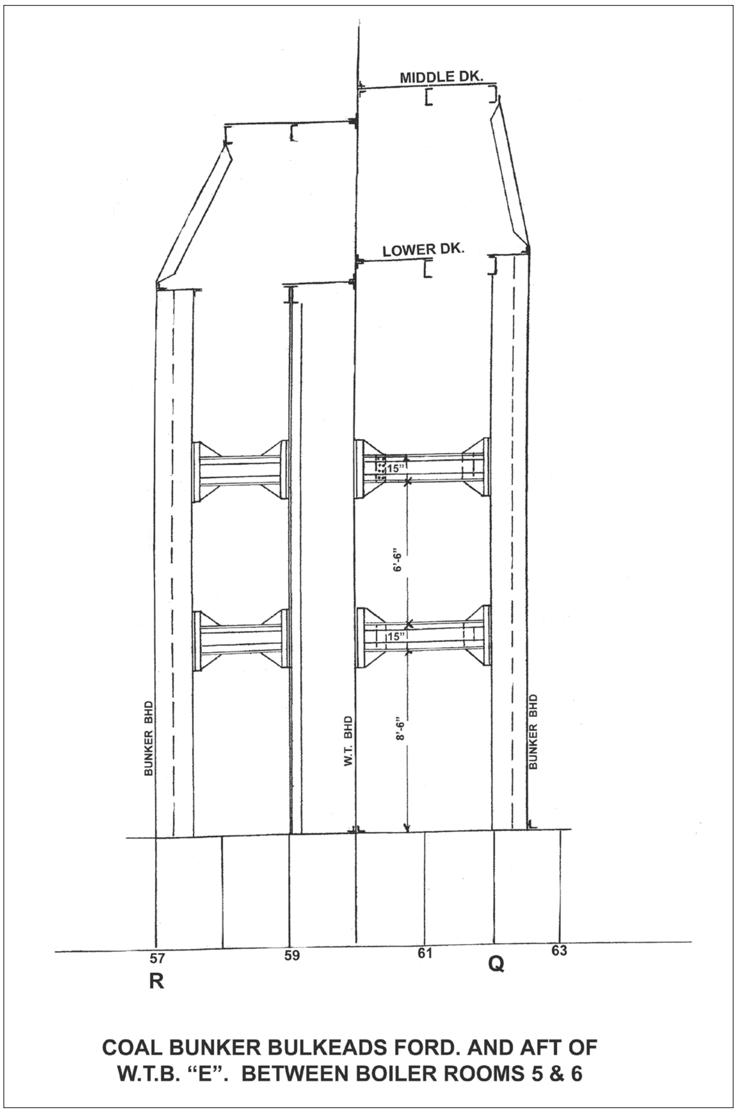

MIDDLE DK.
LOWER DK.
15"
6'-6"
15"
8'-6"
BUNKER BHD
W.T. BHD
BUNKER BHD
57
59
61
63
R
Q
COAL BUNKER BULKEADS FORD. AND AFT OF W.T.B. "E". BETWEEN BOILER ROOMS 5 & 6

Fig. 6-19 **Coal Bunker Bulkheads at WTB E** – A sectional drawing through the cross bunker bulkheads within Nos 5 and 6 Boiler Rooms on either side of WTB E. *(Illustration by Bruce Beveridge based on original H&W bunker drawings)*

Notes

1. The watertight door indication panel seen in James Cameron's 1997 movie 'Titanic' was purely artistic license. A panel indicating the position of the watertight doors was suggested by Chief Engineer Bell after the maiden voyage of *Olympic*, but was not installed until after *Titanic*'s loss.
2. It should be noted here that at the time the *Olympic*-class ships were built, even aboard ships employing the Stone-Lloyd system the fitting of remotely operated doors which were under the direct control of the bridge was restricted to the Tank Top and, occasionally, one or two of the lowest decks of the ship. The remainder of the watertight doors throughout the ship were still manually operated, and on a large liner, these manually operated doors significantly outnumbered those which were controlled centrally.
3. The Firemen's Passage, more commonly referred to as the Firemen's Tunnel, was a fully-enclosed crew passageway between the boiler rooms and the forward spiral stairs leading to the quarters of the Firemen, Greasers and Trimmers in the upper decks. It is described more fully in Chapter 9 of this volume.
4. On nearly all general arrangement plans and written specifications contemporary to the completion of *Titanic*, WTB B is described as being continued as watertight to the underside of D Deck. However, the portion of this bulkhead which existed between E and D Decks has curiously been omitted from the Harland & Wolff drawing detailing the construction of this bulkhead. As it is the authors' desire to favor accuracy over completeness, no attempt has been made to recreate the missing details in the figure which accompanies this chapter.

Chapter 7

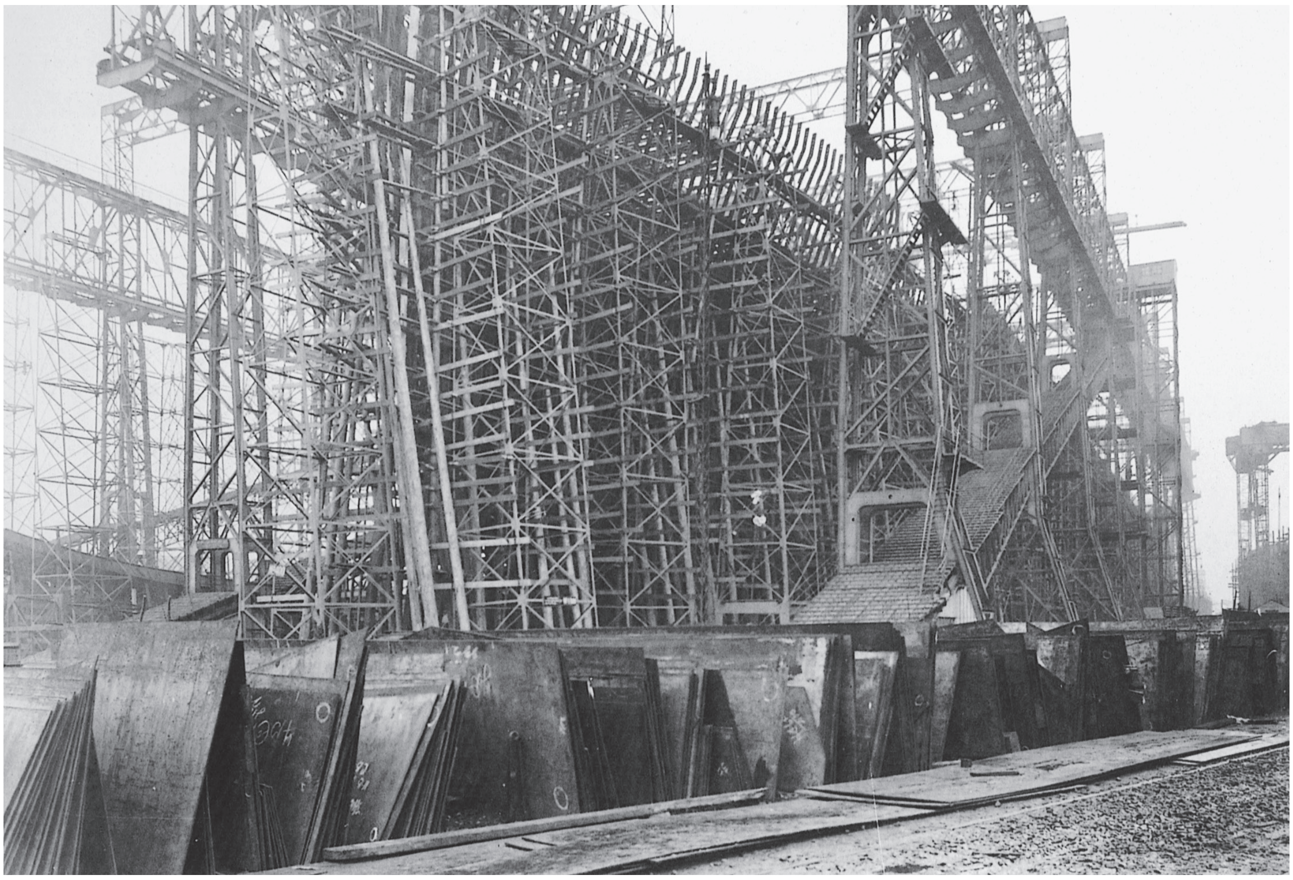
Shell Plating

In steel vessels, the outside shell plating acts as a watertight skin and is the principal structural item in the ship girder. However, the shell plating is only as effective as the structural pieces accompanying it. Although it affords enormous longitudinal strength to the vessel, the shell plating depends upon the assistance of the transverse framing and bulkheads, keelsons, stringers and decks to stiffen it and hold its shape.

Fig. 7-1 **Plating Stored in Yard** – Stacks of steel plates lay stockpiled in the shipyard at the head of the gantry, still unworked and in their rough oversize as delivered from the steel mill. From here, they will be picked as required and delivered to the Platers' Shed for trimming, forming and punching of rivet holes before being delivered to the building berth for hanging-up. *(H&W/Authors' collection)*

Nomenclature

The method of plating the hull of *Titanic* consisted of a combination of two well-known practices. The bottom shell plates from the keel up to the turn of the bilge were fastened in the 'clinker' method, sometimes referred to as the 'clincher' method. In this type of construction, the inboard edge of each strake rested upon the outboard edge of the preceding strake. The shell plates above the turn of the bilge were fastened in the 'in-and-out', or 'sunken-and-raised', system. In this method, the inner plates rested against the frame while the outer plates lapped over the inner plates. In both systems, the individual plates were arranged in horizontal rows called 'strakes'.



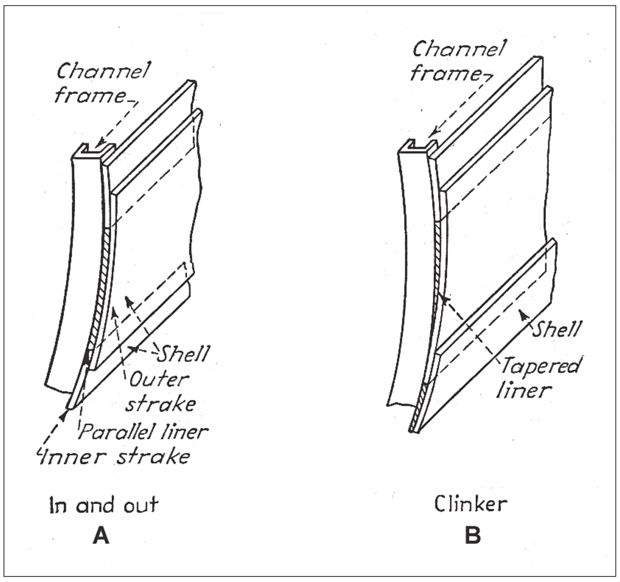


Fig. 7-2 **Examples of Shell Plating Methods** – Shown here are the two primary methods of plating used on the shell plating of *Titanic.* 'A' illustrates the 'In-and-Out' method, while 'B' depicts the 'Clinker' method. Note that while 'B' shows the use of tapered liners, these troublesome liners were eliminated on *Titanic*, where clinker plating was used instead to plate the bottom out to the turn of the bilge. In this case, the plates were attached to joggled angle bar frames instead.

For convenience, the strakes and plates of all ships are identified with some system of letters and numbers. On *Titanic*, the strakes were assigned letters and the individual plates within these strakes were numbered. The first strake was actually the keel plate, identified as the 'A' strake. This strake was 52in wide at its broadest point and was located symmetrically on the centerline of the hull. The garboard strakes adjacent to the keel plate were identified with the letter 'B'. The next strakes outboard of these were 'C' and so forth, continuing around the turn of the bilge and up to the strakes of the Bridge Deck (B), ending at 'Y'. The numbering of the individual plates within each strake commenced with the forward-most plate, identified as number '1'.

Certain universally adopted names are given to the shell strakes to identify their location on the ship. These are: 1) the keel plate, at the very bottom center; 2) the garboard strakes, immediately adjacent to each side of the keel plate; 3) the bilge strakes, located at either side along the turn of the bilge; and 4) the sheer strakes – the highest course of the main hull plating – located just beneath the sheer line. In non-flush methods of shell plating such as the in-and-out and clinker methods, the edges of the plating had a specific nomenclature as well. The overlap of contiguous strakes of plating (those joints in the longitudinal or horizontal orientation) in the above plating methods was termed a 'landing'. When visible from outside the hull, these were called 'sight edges' or 'caulking edges;' an edge visible from inside was called a 'landing edge' or 'molded edge'. Within each strake, the transverse, or vertical, joints at the plate ends (collectively known as 'edge joints') were called 'butts' when flush; when these joints were overlapped, as was generally the case, they were referred to as 'butt laps'. In this form of joint, the lap of the plate forward of the butt was bent, or 'set', outward, while that of the plate aft of the butt was set inward. The surfaces and adjacent edges of any portions of a plate which were to make contact with another plate or frame were respectively termed the 'faying surfaces' and 'faying edges'.

Liners

Regardless of the method of plating employed, in order to insure soundness of construction, it was essential that all plating was firmly and solidly connected to the framework which supported it. When the strakes of shell plating were arranged on the in-and-out system (i.e. inside strakes bearing upon the frames; outside strake landings resting upon the edges of the adjacent inside strakes and forming the seams), something was needed to secure a firm connection between the outside strakes and the frames. With small vessels, the materials used in the construction of the hull were often light enough in nature to permit the 'joggling' of plate edges or the frames in order to permit a solid connection between all surfaces. This, however, was not practical or possible in larger ships like *Titanic* due to the heavy nature of the scantlings. Consequently, there remained a space between the plates of the 'out' strakes and the frames equal to the thickness of the inner plates. Correction of this problem was achieved by filling the space with strips of iron or steel having the same thickness as the adjacent inside strakes. Filler pieces such as these were generally referred to as packing pieces or 'liners'. The term 'packing iron' was also used by some shipwrights as a generic name for such liners. However, use of this term was discouraged at Harland & Wolff and other high-quality builders as the term 'packing iron' also denoted a class of brittle and inferior iron that was used as a liner material by less scrupulous shipyards.

While the use of liners provided a simple solution to providing a sound connection between the faying surfaces of the 'out' strakes and the frames, there were drawbacks that discouraged their use elsewhere. The more serious of these drawbacks included the difficulty in obtaining work free from defects when riveting through more than two thicknesses, and the additional weight these liners added to the completed vessel. Therefore, use of liners was eliminated in the comparatively thin

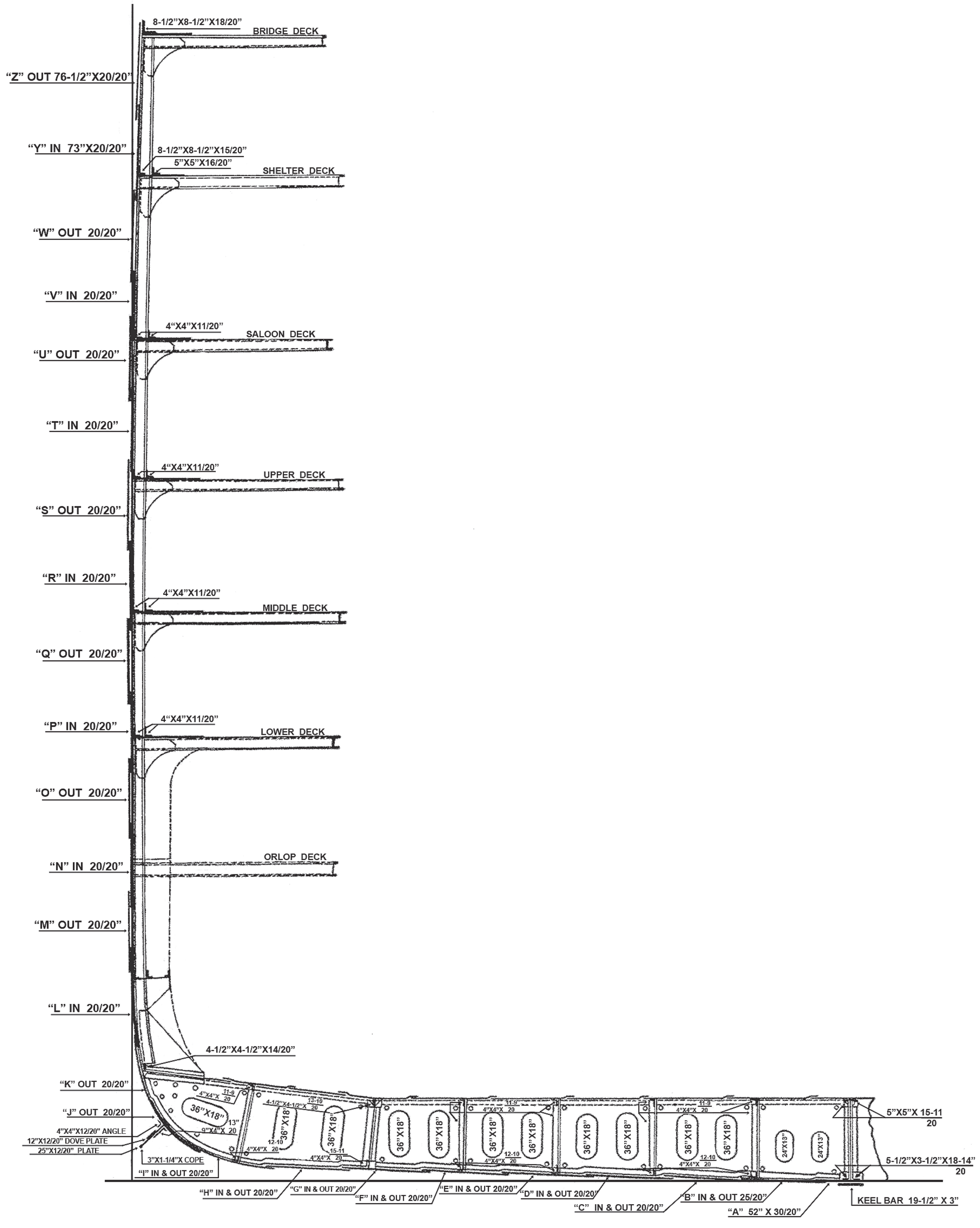

8-1/2"X8-1/2"X18/20"
BRIDGE DECK
"Z" OUT 76-1/2"X20/20"
"Y" IN 73"X20/20"
8-1/2"X8-1/2"X15/20"
5"X5"X16/20"
SHELTER DECK
"W" OUT 20/20"
"V" IN 20/20"
4"X4"X11/20"
SALOON DECK
"U" OUT 20/20"
"T" IN 20/20"
4"X4"X11/20"
UPPER DECK
"S" OUT 20/20"
"R" IN 20/20"
4"X4"X11/20"
MIDDLE DECK
"Q" OUT 20/20"
"P" IN 20/20"
4"X4"X11/20"
LOWER DECK
"O" OUT 20/20"
"N" IN 20/20"
ORLOP DECK
"M" OUT 20/20"
"L" IN 20/20"
4-1/2"X4-1/2"X14/20"
"K" OUT 20/20"
"J" OUT 20/20"
4"X4"X12/20" ANGLE
12"X12/20" DOVE PLATE
25"X12/20" PLATE
3"X1-1/4"X COPE
"I" IN & OUT 20/20"
4"X4"X 11-9/20
36"X18"
13"
9"X4"X 20
4-1/2"X4-1/2"X 13-10/20
12-10
4"X4"X 20
15-11
4"X4"X 20
36"X18"
11-9
12-10
24"X13"
5"X5"X 15-11/20
5-1/2"X3-1/2"X18-14"/20
"H" IN & OUT 20/20"
"G" IN & OUT 20/20"
"F" IN & OUT 20/20"
"E" IN & OUT 20/20"
"D" IN & OUT 20/20"
"C" IN & OUT 20/20"
"B" IN & OUT 25/20"
"A" 52" X 30/20"
KEEL BAR 19-1/2" X 3"

Fig. 7-3 **Midship Half-Section** – This Midship half-section of *Olympic* and *Titanic* identifies the individual strakes by letter and indicates the thicknesses of these strakes amidships. The letter 'X' was not generally used on construction drawings of any sort because it could be easily confused with other drafting symbols. However, the letter 'X' was used in the case of these ships to indicate a 'dropped' strake near the sheer line, which appeared at either end of the ship. The half section midship scantlings released to the Board of Trade, as is shown in Chapter 1 of this volume, indicates the letter 'X.' However, plans such as this true midship section have the letter absent. *(Illustration by Bruce Beveridge based on original H&W Shell Plating Plan)*

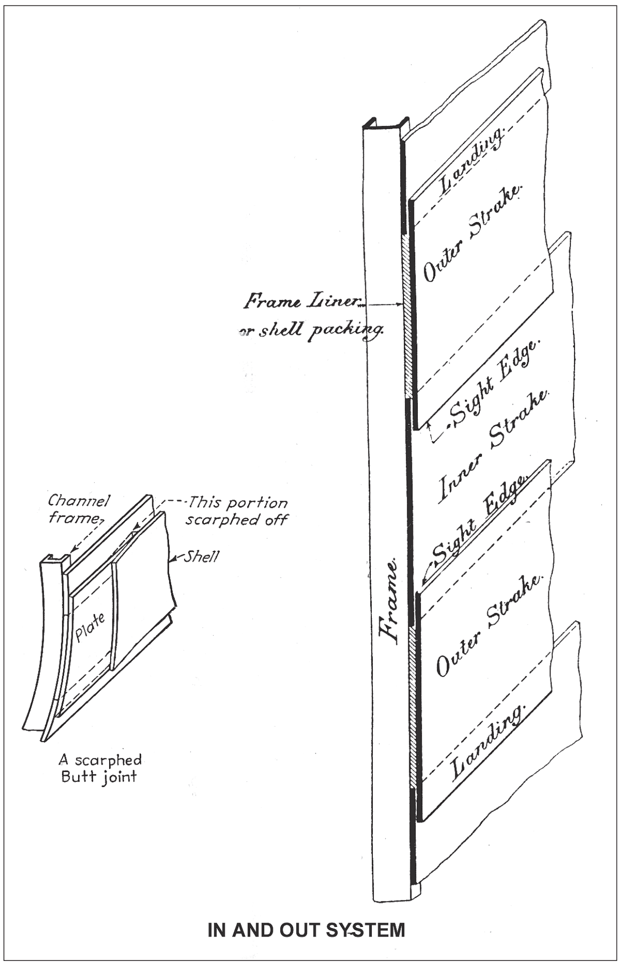


Fig. 7-4 **In-and-Out Plating Nomenclature.**

deck and Tank Top plating by joggling the overlapping edges of the butts and landings.

In the case of the clinker-style shell plating employed below the turn of the bilge, the most common (and troublesome) practice in use at the time was to fit tapered liners between the plates and frames. The principal problem encountered with tapered liners was their tendency to be somewhat fragile at the thin end, making it difficult at times to obtain a consistently solid connection against the frame across the full width of a plate. Additionally, the thin end of the liner was more prone to wasting due to corrosion, thereby weakening the connection between the plate and frame. To eliminate the need for tapered liners, the designers at Harland & Wolff devised a method whereby these plates were riveted to angle-bar frames of relatively thin section that had been machine-joggled prior to being attached to the tank floors. This resulted in both superior workmanship and a considerable saving in weight.

To eliminate the need for packing where the landings of the outside strakes passed over the raised butt laps in the adjacent inside strakes, the corners of the raised lap of the butt behind the landing was planed off in a tapered form creating a feathered edge, or 'scarf'. These scarfs allowed the outside strakes to bear tightly against the inside strakes. The inward-protruding edges of the butt laps of the outer strakes were finished in the same manner. In this case, the scarfs were planed into the corners of the inboard forward edge of each plate. This allowed the landings of the inside strakes to bear tightly upon the inner faces of the outside strakes. Without these scarfs a tapered aperture would have remained, necessitating the introduction of numerous small tapered packing pieces.

Among the more important considerations in the arrangement of the shell plating was ensuring a good disposition of the butts. This offsetting of the relative positions of end joints was known as 'shift'. In achieving 'good shift', as it was termed, no butts in adjacent strakes were permitted to come nearer to one another than two frame spaces, with a shift of three or four spaces being typical. Furthermore, no shell plate was made less than seven frame spaces in length, the only exception to this rule being the plates at the extreme ends of the ship, where maintaining such an arrangement was not possible. A further consideration in arranging the shifting of end joints was the avoidance, particularly amidships, of a number of joints forming a zigzag vertical line which would create an area of considerable transverse weakness.

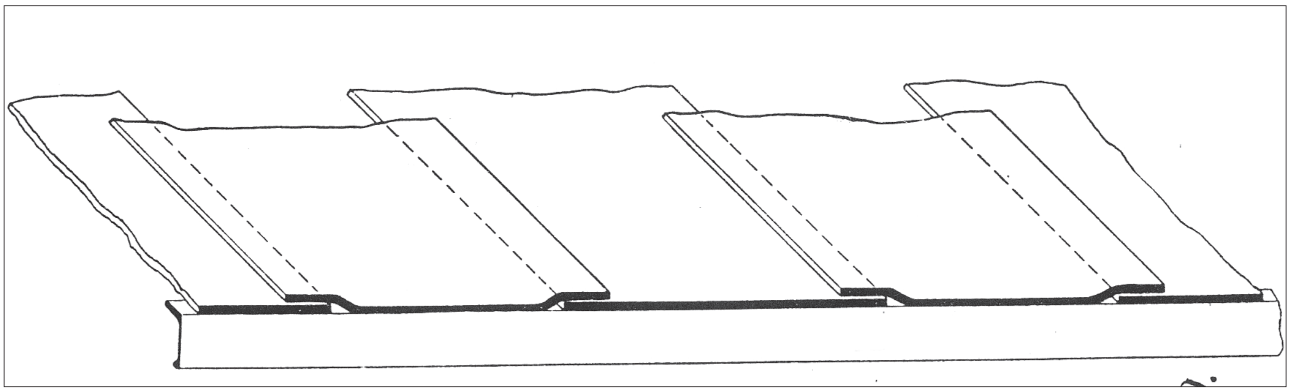


Fig. 7-5 **Joggled Plating** – Joggled plating as was used on *Titanic*'s decks and Tank Top.

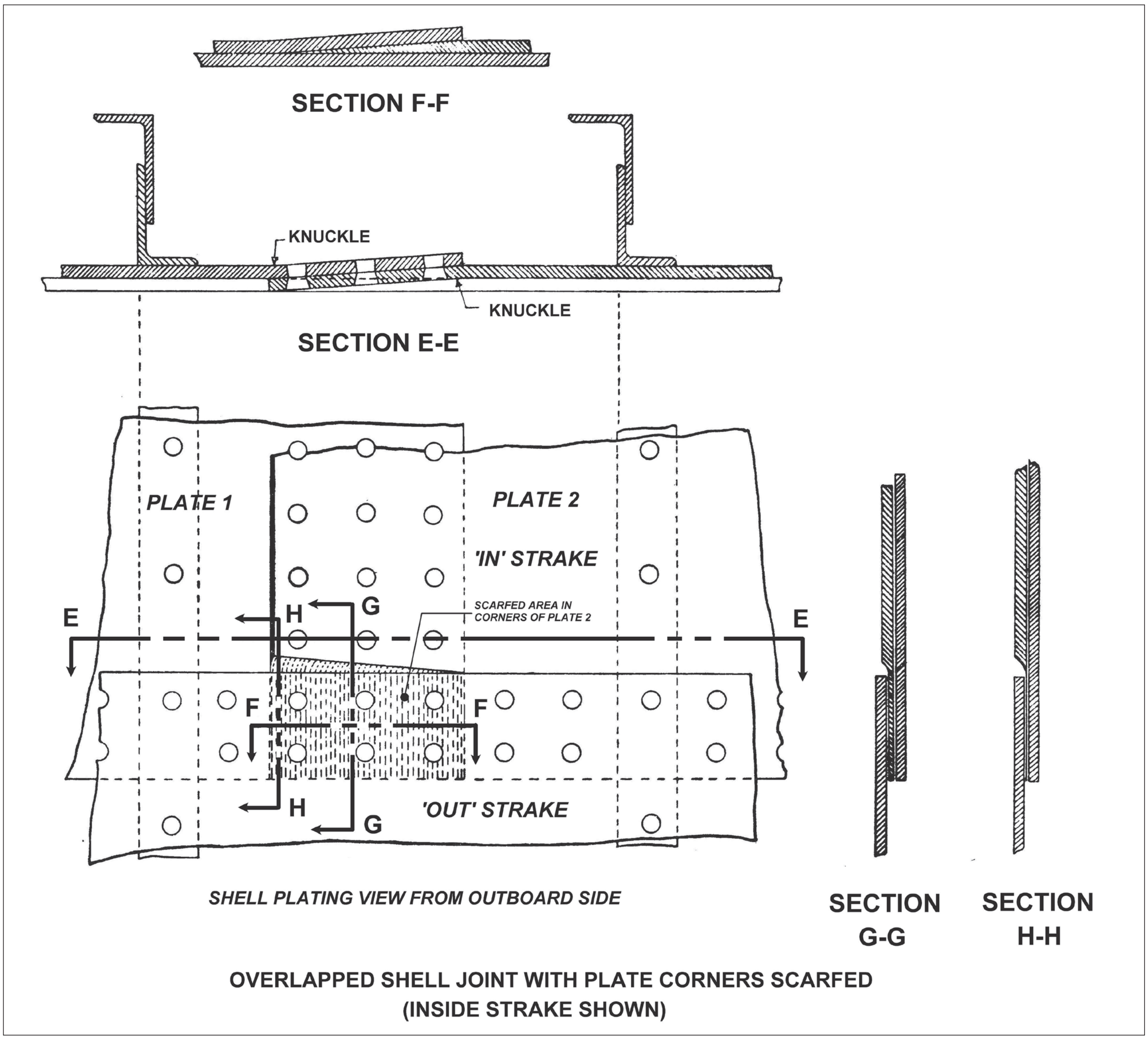

SECTION F-F
KNUCKLE
KNUCKLE
SECTION E-E
PLATE 1
PLATE 2
'IN' STRAKE
SCARFED AREA IN CORNERS OF PLATE 2
E
E
H
G
F
F
H
G
'OUT' STRAKE
SHELL PLATING VIEW FROM OUTBOARD SIDE
SECTION G-G
SECTION H-H
OVERLAPPED SHELL JOINT WITH PLATE CORNERS SCARFED
(INSIDE STRAKE SHOWN)

Fig. 7-6 **Scarfed Butt-Lap Corners** – 'In' Strakes. *(Scott Andrews collection)*

Preparation of plates

In preparing a shell plate for its position in the ship, the position of all frame rivet holes (which, for the most part, were punched before the frames were erected) and the rivet holes in the seams of adjacent plates were transferred to the new plate by means of a template.

The template was a framework made of thin wood large enough to cover the area of the plate, having wooden bars across in way of each frame. This was pinned on to the vessel in exactly the same position that the plate itself would occupy and, by means of chalk, the positions of the rivet holes were transferred to the template.

The template was then removed and laid upon the shell plate. Using what was called a 'reversing tool', the rivet holes were re-transferred to the plate, which was then carried away to the Platers' Shop to be punched,

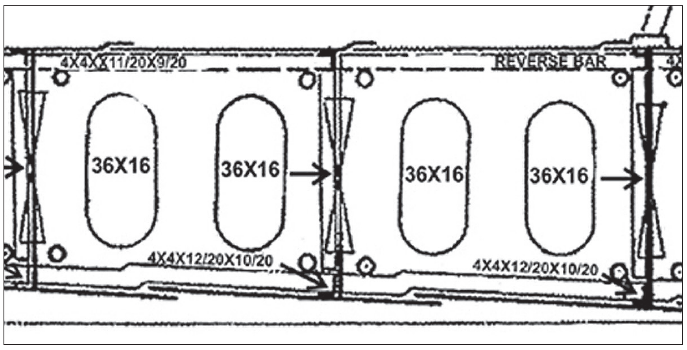

4X4XX11/20X9/20
REVERSE BAR
36X16
36X16
36X16
36X16
4X4X12/20X10/20
4X4X12/20X10/20

Fig. 7-7 **Joggled Frames** – The angle-bar frames below the turn of *Titanic*'s bilge were joggled to give a flat surface to which the plates were riveted. This eliminated the liners otherwise needed, resulting in superior workmanship and a reduction in weight. *(Illustration Bruce Beveridge based on original H&W Midship Section)*

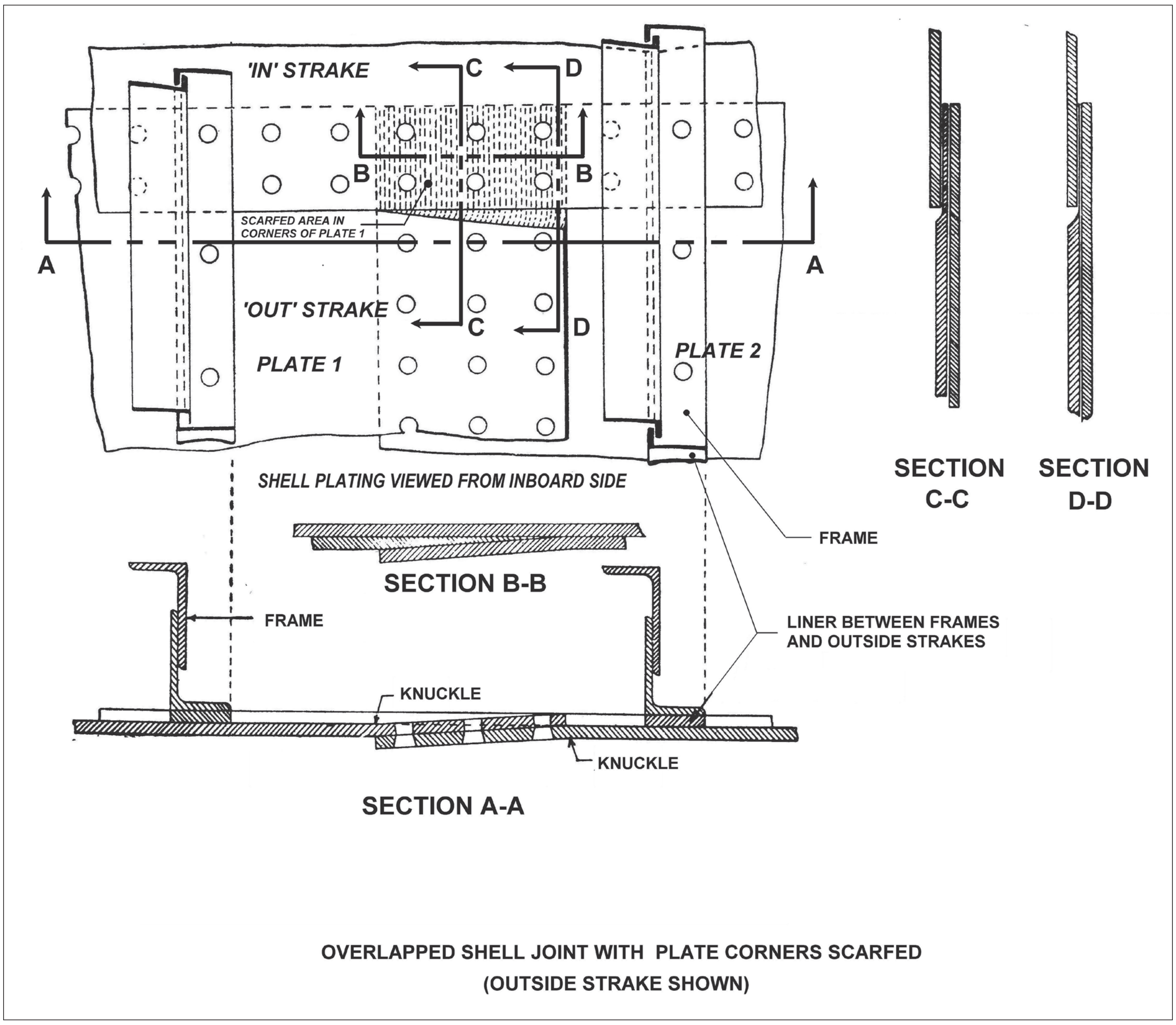

'IN' STRAKE
C
D
B
B
SCARFED AREA IN CORNERS OF PLATE 1
A
A
'OUT' STRAKE
C
D
PLATE 1
PLATE 2
SHELL PLATING VIEWED FROM INBOARD SIDE
SECTION C-C
SECTION D-D
FRAME
SECTION B-B
FRAME
LINER BETWEEN FRAMES AND OUTSIDE STRAKES
KNUCKLE
KNUCKLE
SECTION A-A
OVERLAPPED SHELL JOINT WITH PLATE CORNERS SCARFED
(OUTSIDE STRAKE SHOWN)

Fig. 7-8 **Scarfed Butt-Lap Corners – 'Out' Strakes.** *(Scott Andrews collection)*

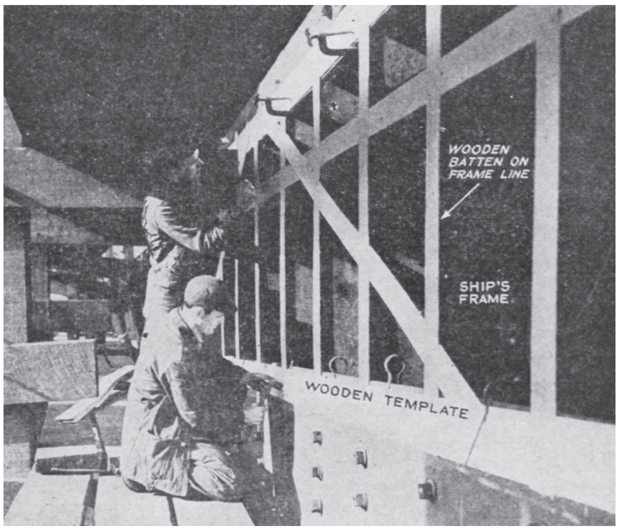

WOODEN BATTEN ON FRAME LINE
SHIP'S FRAME
WOODEN TEMPLATE

Fig. 7-9 **'Lifting' a Steel Plate** – At times it was difficult to accurately lay off the shape of a plate from a Mold Loft floor. In such a case, a mold, or template, was made directly from the ship. This process was known as 'lifting' a plate. The template was then returned to the Platers' Shed, where it was used to lay off, cut and roll the required plate to the indicated shape.

countersunk, and sheared to its finished size. All punching of holes was done from the faying surfaces. The plate was then lifted into position on the ship by a gantry winch and then securely bolted in place with a sufficient number of temporary bolts to bring the plate into complete contact with all surfaces against which it fayed. As the riveting progressed, the temporary bolts were removed and replaced by rivets.

The riveting of each plate was begun from the center and progressed toward the outer edges. By doing so, if any slight expansion occurred due either to hammering or heat from the rivets, it was evenly distributed in all directions and was therefore practically unnoticeable. This was especially important when fitting the largest plates.

In those parts of the shell where there was considerable change in the molded form of the hull within a small area, the exact curvature of the plate was ascertained by strips of bar iron called 'set irons'. These were bent to the correct shape at two or more positions within the

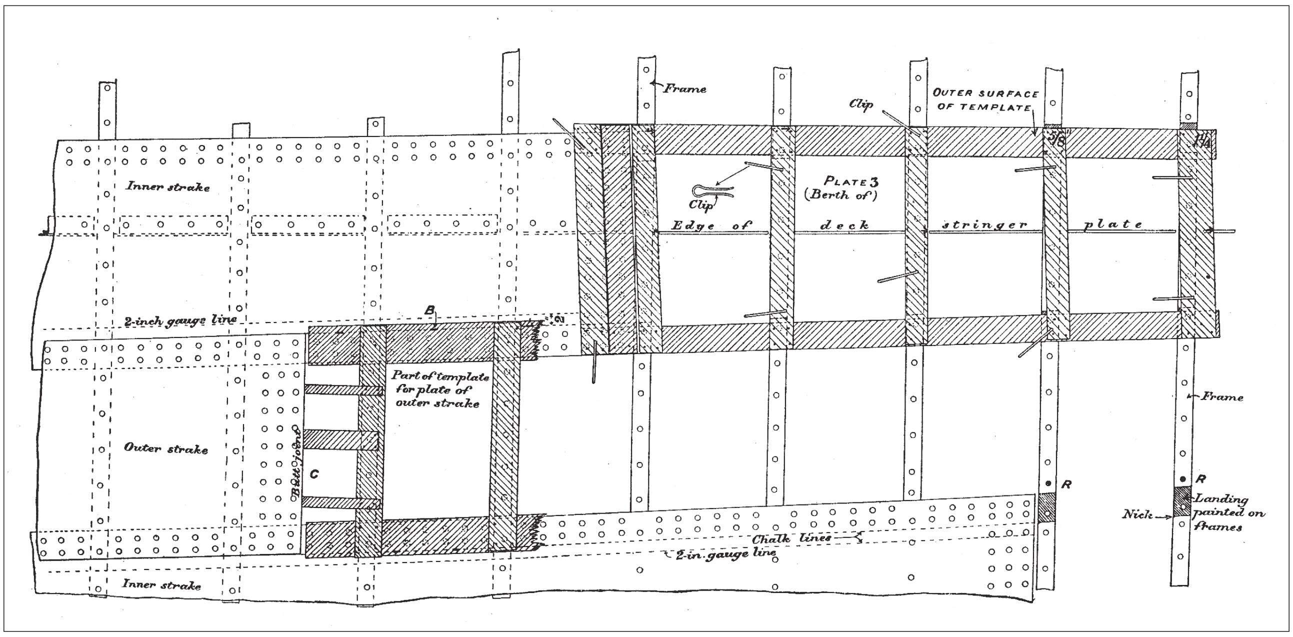

Frame
Clip
OUTER SURFACE OF TEMPLATE
5/8"
1 1/4"
Inner strake
Clip
PLATE 3 (Berth of)
Edge of deck stringer plate
2-inch gauge line
B
Part of template for plate of outer strake
Butt joint
C
Outer strake
Frame
R
R
Nick
Landing painted on frames
Chalk lines
2-in. gauge line
Inner strake

Fig. 7-10 **Creating a Plate Template** – This drawing illustrates the manner in which templates for plates were constructed in place on the ship in instances when it was desired to 'lift' the plate directly from the hull. This was often the most practical way to create patterns for plates having very complex shapes, and was also especially useful in preparing replacement plates for ship repair work.

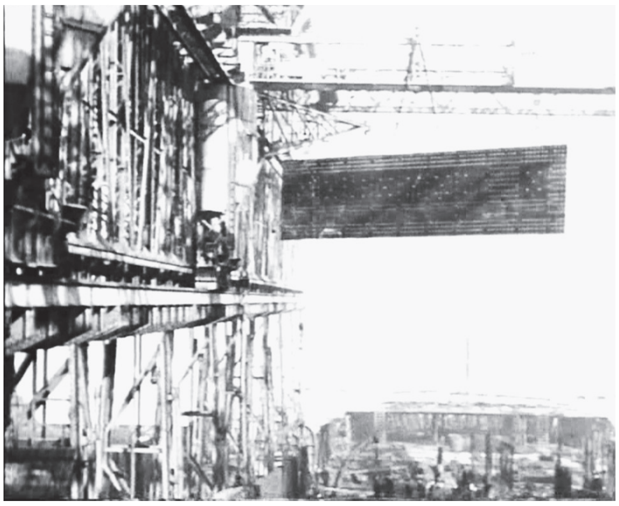


Fig. 7-11 **Hoisting a Plate From the Gantry**. *(From an original period film/Robert Hahn collection)*

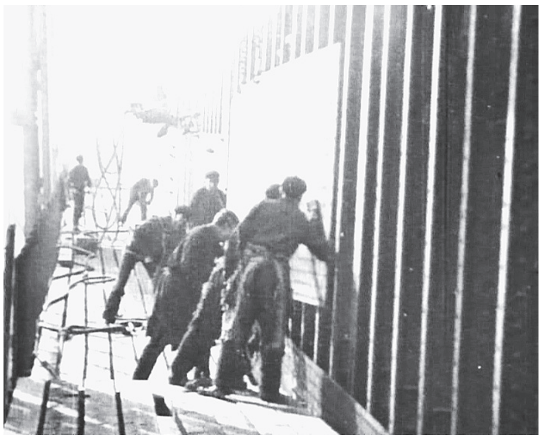


Fig. 7-12 **Setting the Plate in Position**. *(From an original period film/Robert Hahn collection)*

length of the plate being prepared. The majority of shell plates could be bent to their required shape with rolling machines manipulated by skillful platers. Plates of more irregular shape needed to be 'furnaced' and hammered into the required form. They were then annealed to relieve the resultant work-hardening which would have otherwise left the material brittle.

Size and thickness of plates

The average shell plate on *Titanic*'s midship section was 6ft wide and, on average, 30ft long, with the largest plates ranging up to a length of 36ft and weighing 4¼ tons each. The thickness of the shell plates was generally 1in for approximately one half the ship's length about the area amidships, especially in those areas requiring extra strength. The thickness of the plating was gradually reduced within most strakes to $^{12}/_{20}$in at the fore and aft ends, with the ending thickness of some strakes being either thinner or thicker as design considerations dictated.

Where the keel and the area beneath the stern frame were concerned, regulations required heavier plating. Consequently, the thickest shell plates were found amidships in the keel plate (the 'A' strake) at $^{30}/_{20}$ in,

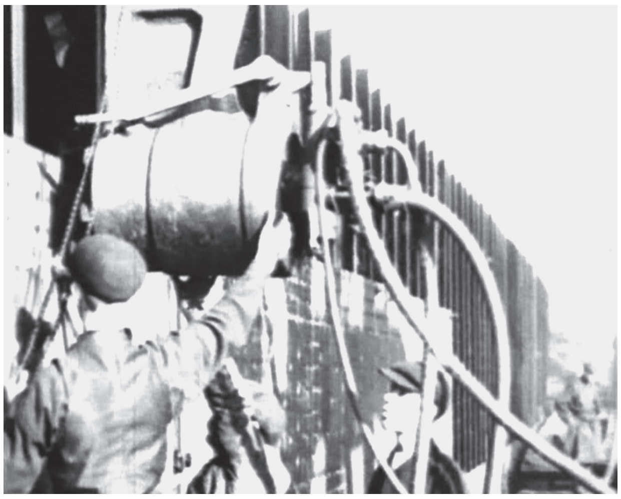


Fig. 7-13 **Hydraulic Riveting of a Plate** – The plate is hydraulically riveted to the frames. *(From an original period film/ Robert Hahn collection)*

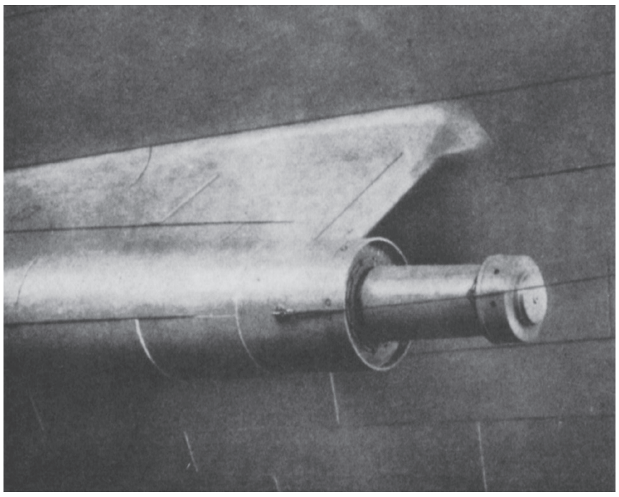


Fig. 7-14 **Plating Around the Port Wing Boss** – Plating around the port wing boss. These plates were 1 inch thick and had to be furnaced and hammered to shape. *(*The Shipbuilder*/ Authors' collection)*

tapering to $^{24}/_{20}$ in at the ends. Particularly in the case of the keel, the need for such heavy plating is easily appreciated given the possibility of a ship running aground and the subsequent severe wear and tear on the hull.

In order to withstand the severe pounding which ships experienced when driving ahead and plunging into head seas, additional internal support to the shell was provided through approximately one eighth of the vessel's length from the stem. This was achieved by carrying all intercostals between the floors in this region as far forward as possible, by introducing additional intercostals, and by doubling the frames around the lower girth of the shell in this locality, in which case two flanges instead of one would be used to support the shell plating. This was done on every other frame up to the height of the Orlop Deck commencing with 93F to 113F, and then on every frame through 134F; after this alternate spacing was resumed for the last of these at frames 136F, 138F and 140F.

The shell plating below the load line in the vicinity of the stern frame and shaft brackets was of greater thickness than the surrounding plates immediately above and just forward of this area, and made of the same heavy 1in plating used amidships. The additional thickness of the plates added greatly to the overall strength of the shaft bosses and brackets, structures which were often subjected to severe vibration as the propellers were lifted above the surface and then submerged as the ship drove through heavy seas. Due to the often-complex compound curves of the boss plates and the shell plating around the propeller aperture, these plates had to be furnaced and hammered in order to be brought to their required shape; these plates were then annealed before being fixed in position.

The shell plating at the fore end of the hull, commencing about 20 to 30ft before the stem, was often made thicker than the surrounding plating to enable the vessel to more effectively resist 'panting' action and to minimize the tendency in lightly-built vessels to 'fall hollow' between the frames owing to the pressure upon the bow when driving ahead. The increased thickness also allowed for navigation through the 4 to 6in of ice which commonly choked northeastern American and eastern Canadian ports in the dead of winter. In *Titanic*'s case, the forward shell plating was already of such substantial thickness that only the reduction of the frame spacing forward of WTB A at frame 134F was required to adequately address these issues.

Compensation was introduced wherever the shell plating was weakened owing to excessive perforation by rivet holes or by the cutting of doors or openings of any kind. In way of all watertight bulkheads, where the shell was perforated by rows of closely spaced rivet holes, the resulting weakness was overcome by fitting bulkhead liners at the outside strakes. When sidelights were cut through a strake, compensation for weakening the strake was accomplished either by increasing the thickness or doubling the plating, or fitting heavy angle bars for at least one frame space in length over all such openings. When openings for doors of any kind were cut through the shell plating, compensation was made by fitting doubling plates above and below these openings, by framing the opening with heavy angle bars, by fitting vertical webs upon each side of the opening, and by installing a fore-and-aft girder upon the shell above these openings. These girders would extend a few feet fore and aft on each side of the doorway.

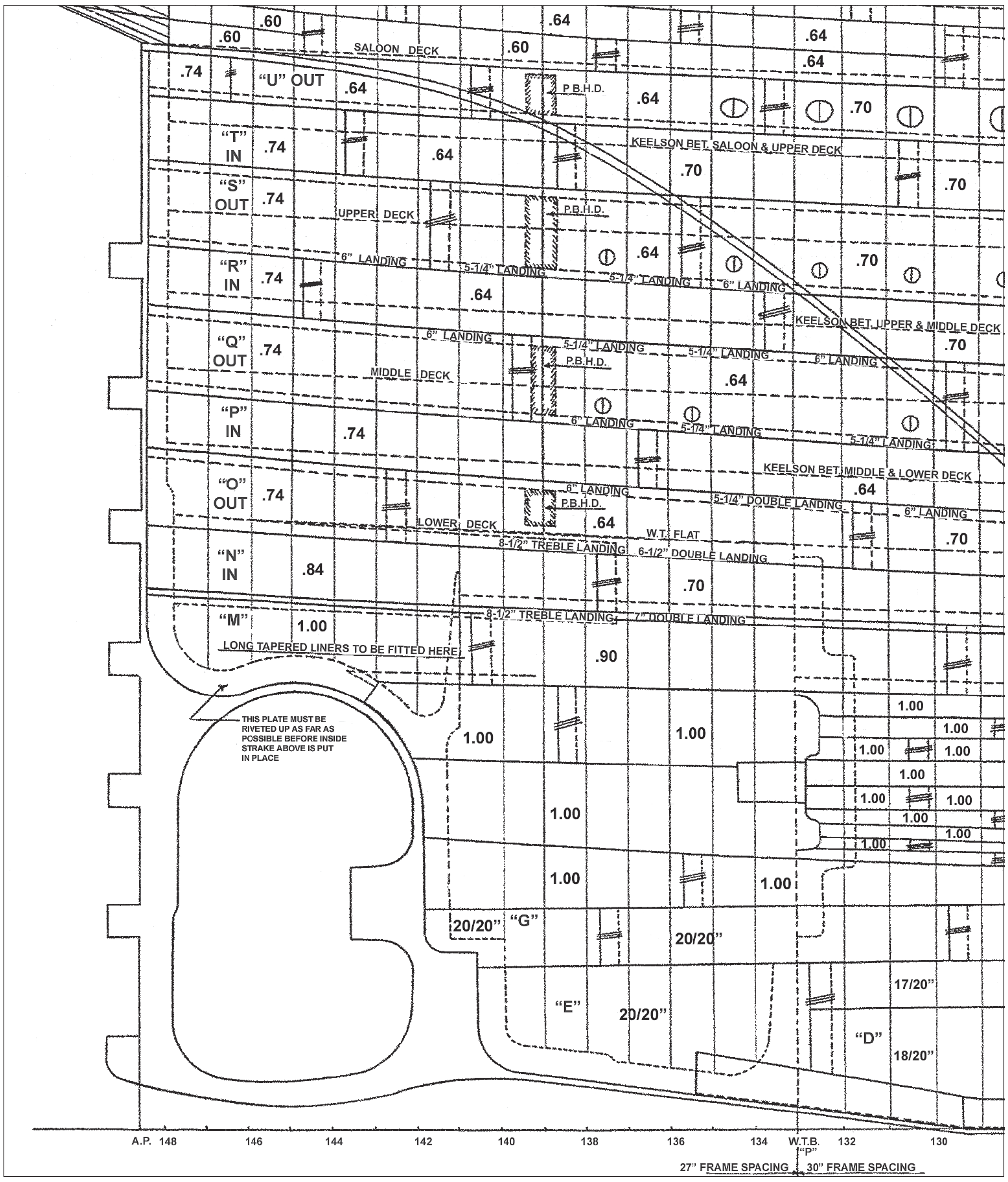

.60
.60
SALOON DECK
.60
.64
.64
.64
.74
"U" OUT
.64
P.B.H.D.
.64
.70
"T" IN
.74
.64
KEELSON BET. SALOON & UPPER DECK
"S" OUT
.74
.70
.70
UPPER DECK
P.B.H.D.
"R" IN
.74
6" LANDING
5-1/4" LANDING
.64
5-1/4" LANDING
6" LANDING
.70
.64
KEELSON BET. UPPER & MIDDLE DECK
"Q" OUT
.74
6" LANDING
5-1/4" LANDING
P.B.H.D.
5-1/4" LANDING
6" LANDING
.70
MIDDLE DECK
.64
"P" IN
.74
6" LANDING
5-1/4" LANDING
5-1/4" LANDING
KEELSON BET. MIDDLE & LOWER DECK
"O" OUT
.74
6" LANDING
P.B.H.D.
5-1/4" DOUBLE LANDING
.64
6" LANDING
LOWER DECK
.64
W.T. FLAT
8-1/2" TREBLE LANDING
6-1/2" DOUBLE LANDING
.70
"N" IN
.84
.70
"M"
1.00
8-1/2" TREBLE LANDING
7" DOUBLE LANDING
LONG TAPERED LINERS TO BE FITTED HERE
.90
THIS PLATE MUST BE RIVETED UP AS FAR AS POSSIBLE BEFORE INSIDE STRAKE ABOVE IS PUT IN PLACE
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
1.00
20/20"
"G"
20/20"
17/20"
"E"
20/20"
"D"
18/20"
A.P. 148
146
144
142
140
138
136
134
W.T.B. "P"
132
130
27" FRAME SPACING
30" FRAME SPACING

Fig. 7-15 **Plating In Way of Stern Frame** – In this plan of the plating around the stern frame, bulkhead liners for the 'out' strakes are seen here as the boxes indicated as 'P.B.H.D.' (P-Bulkhead). Notice the heavier plating around the stern frame, and that the thicknesses of the plates change from decimals to fractions at the 'G' strake. *(Illustration by Bruce Beveridge based on the original H&W Shell Plating Plan)*

Some parts of the shell plating required more strength than others. The usual practice in seagoing vessels was to increase the thickness of the plating on the topsides, particularly in the sheer strake and in the strake beneath. In the case of *Titanic*, these strakes were doubled. The term 'doubled' does not necessarily mean that the overall plating thickness was increased by exactly 100 per cent. It means that plating was thickened by the addition of another layer of plating added in proportion to the amount of load to be carried or in proportion to the calculated loss in strength resulting from an opening cut in the plate. In very large vessels such as *Titanic*, with her extreme length in proportion to her depth, doublers were fitted to the sheer strake amidships and to the strake immediately above at B Deck.

The butts of these doublers were connected by means of both single and double butt straps. Doubling of the shell plating was also carried out for 3/5 the length of the vessel in the plating of the 'J' strake located midway through the turn of the bilge. The bilge plating formed the lower extremity of the ship girder, just as the sheer strake formed the upper. Doubling plates were fitted around hawse pipes and the bulwark plating at the ends of the Poop and Forecastle Decks. These were increased in thickness in order to reduce the sudden interruption in longitudinal strength which these structures created. All openings through the bulwarks for wash port doors or mooring ropes had narrow doubling plates fitted around them.

Further protection was required in the area beneath the hawse pipes in order to prevent the rubbing and chafing action of the anchor cables wearing away the landing edges of the outer strakes. This was provided in the form of 3¼in x ¾in beveled strips fitted to the lower landing edges.

The thicknesses and riveting of *Titanic*'s shell varied considerably, and can only be properly illustrated with a plan, as opposed to a list of specifications. At the bow

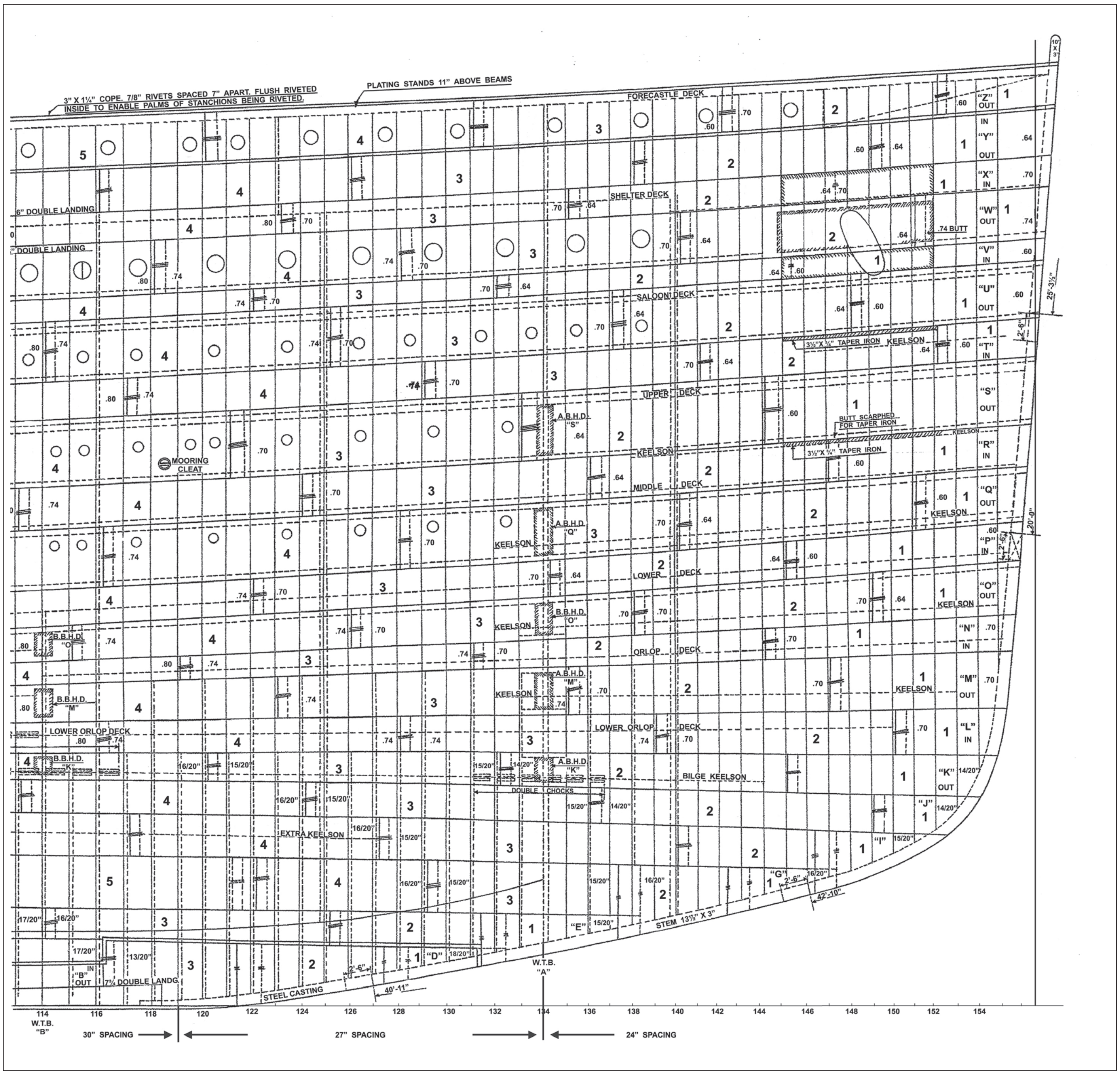

3" X 1¼" COPE, 7/8" RIVETS SPACED 7" APART, FLUSH RIVETED INSIDE TO ENABLE PALMS OF STANCHIONS BEING RIVETED.
PLATING STANDS 11" ABOVE BEAMS
FORECASTLE DECK
SHELTER DECK
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
ORLOP DECK
LOWER ORLOP DECK
6" DOUBLE LANDING
DOUBLE LANDING
MOORING CLEAT
3½"X¾" TAPER IRON KEELSON
BUTT SCARPHED FOR TAPER IRON
KEELSON
A.B.H.D. "S"
A.B.H.D. "Q"
A.B.H.D. "O"
A.B.H.D. "M"
A.B.H.D. "K"
B.B.H.D. "O"
B.B.H.D. "M"
B.B.H.D. "K"
BILGE KEELSON
DOUBLE CHOCKS
EXTRA KEELSON
STEM 13½" X 3"
STEEL CASTING
7½ DOUBLE LANDG
"Z" "Y" "X" "W" "V" "U" "T" "S" "R" "Q" "P" "O" "N" "M" "L" "K" "J" "I" "G" "E" "D" "B"
OUT
IN
W.T.B. "A"
W.T.B. "B"
114 116 118 120 122 124 126 128 130 132 134 136 138 140 142 144 146 148 150 152 154
30" SPACING
27" SPACING
24" SPACING

Fig. 7-16 **Drawing of *Titanic*'s Bow Plating** – This drawing of *Titanic*'s bow plating shows the arrangement and thicknesses of plates, the doublings at and around the hawse hole, etc. *(Illustration by Bruce Beveridge based on original H&W Shell Plating Plan)*

and stern where the ship narrowed, the changes in size and form of the plate types employed varied from those visible amidships considerably. The information compiled in the following tables was obtained from the original 400-1 midship section of 1908. A second midship section exists dating from the *Olympic*'s 1913 refit and, in some cases, specifies a slight difference in some plate thicknesses. The information following is that which is noted on the original midship section. It should also be noted that the measurements indicated are reproduced in their original fractional form; hence $^{20}/_{20}$ths of an inch is equal to 1in, $^{30}/_{20}$ths of an inch is equal to 1½in and so on. The table on page 150 is a summary of the range of thicknesses of steel plates employed in each strake of *Titanic*'s shell plating, but do not include references to local increases in thickness around the shaft bossings, etc.

Bilge keels

Bilge keels were fitted for about 295ft of the vessel's length amidships to minimize rolling in a seaway. Bilge keels are projecting fins attached to the outside shell plating along the turn of the bilge, the resistance of which, as they oscillate with the rolling movements of the vessel, reduce the rolling motion of the vessel.

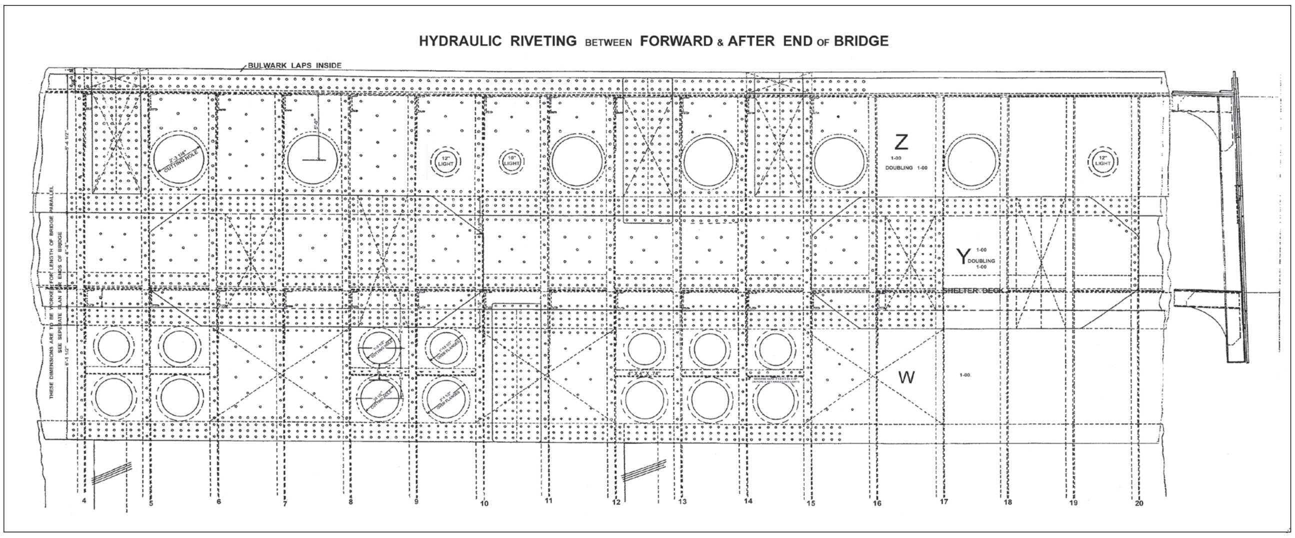

HYDRAULIC RIVETING BETWEEN FORWARD & AFTER END OF BRIDGE
BULWARK LAPS INSIDE
THESE DIMENSIONS ARE TO BE WORKED FOR LENGTH OF BRIDGE PARALLEL
SEE SEPARATE PLAN FOR ENDS OF BRIDGE
2'-3 1/4" CUTTING HOLE
12" LIGHT
10" LIGHT
Z
1-00
DOUBLING 1-00
Y
1-00
DOUBLING
1-00
SHELTER DECK
W
1-00
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Fig. 7-17 **Hydraulic Riveting Along the Sheer** – This plan shows the hydraulic riveting amidships within the 'W,' 'Y' and 'Z' strakes. The arrangement of the doubler plates is well illustrated here as well, including the octagonal plates so familiar to those who are familiar with in *Titanic*'s external appearance. *(Illustration by Bruce Beveridge based on original H&W Hydraulic Riveting Plan)*

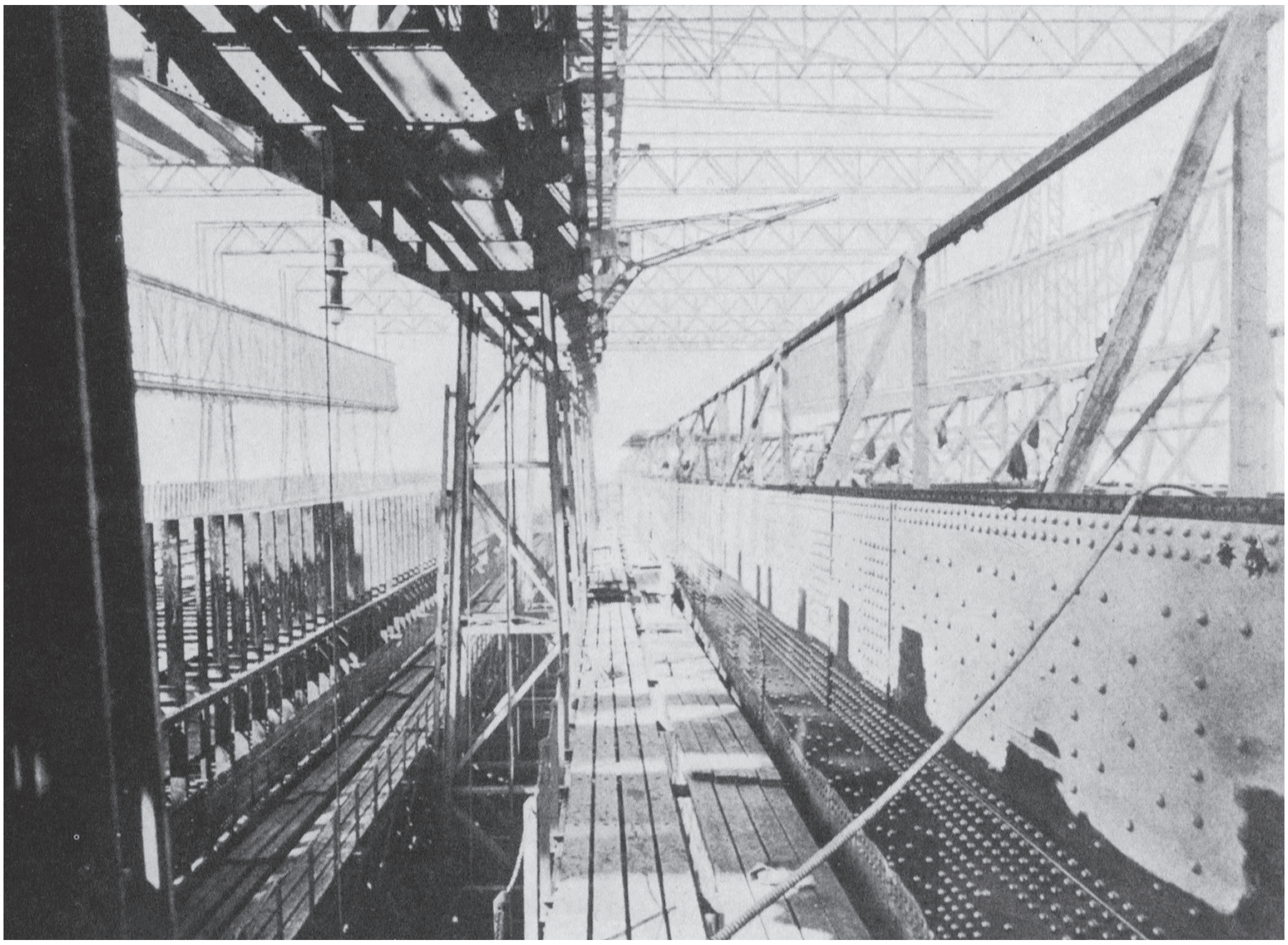


Fig. 7-18 **Shell Plating Along *Olympic*'s Sheer Line** – A view looking aft along *Olympic*'s hull, with the frames of *Titanic* to the left. Here, the plating has been nearly completed to the Bridge Deck (B) level, while temporary wooden staging has been erected preparatory to commencing the framework of the Promenade Deck (A). *(*The Shipbuilder*/Authors' collection)*

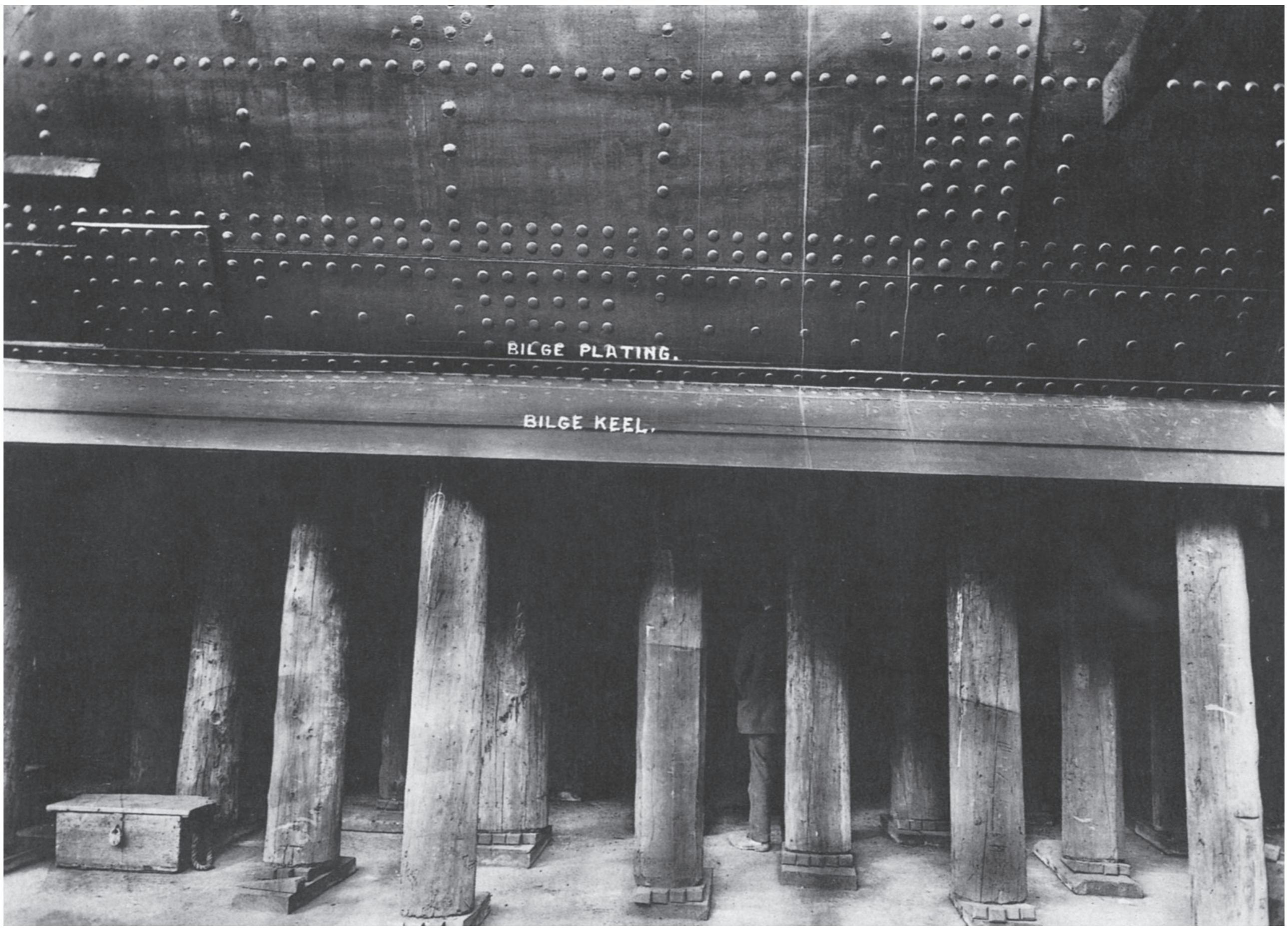
Thicknesses of Steel Plates

Strakes 'A' through 'I' fastened clinker-style on joggled frames

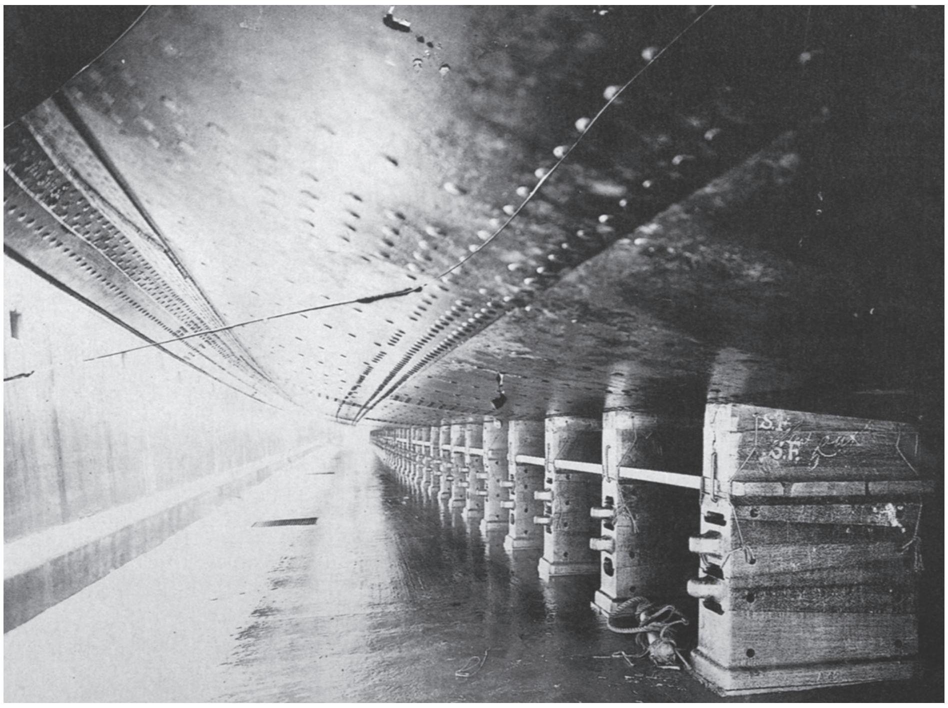
A Strake	keel plate $^{30}/_{20}$ tapering to $^{24}/_{20}$ in
B Strake	$^{25}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{18}/_{20}$ at ends of hull (garboard strakes)
C Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{12}/_{20}$ at ends of hull
D Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{12}/_{20}$ at ends of hull
E Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{12}/_{20}$ at ends of hull
F Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{12}/_{20}$ at ends of hull
G Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{12}/_{20}$ at ends of hull
H Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length tapering to $^{12}/_{20}$ at ends of hull
I Strake	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends of hull
Internal doubling at turn of bilge	$^{20}/_{20}$ for $^{2}/_{5}$ Length; then $^{15}/_{20}$ to $^{3}/_{5}$ Length aft and to frame 90F

Turn of Bilge to Bridge Deck (B): 'out' specifies outside strake, and 'in' specifies inside strake

J Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull – $^{22}/_{20}$ at ends of doubling. $^{20}/_{20}$ doubling for $^{2}/_{5}$ Length, then $^{15}/_{20}$ to $^{3}/_{5}$ Length aft and Frame 90F
K Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends (butts hydraulically riveted)
L Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends of hull
M Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends of hull
N Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends of hull
O Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull (Bottom: treble-riveted to $^{3}/_{5}$ Length aft and ¾ Length forward; Top: quadruple-riveted from $^{1}/_{5}$ Length to $^{3}/_{5}$ Length; treble-riveted amidships and to ¾ Length
P Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull
Q Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull (Bottom and Top: quadruple-riveted from $^{1}/_{5}$ Length to $^{3}/_{5}$ Length; treble-riveted amidships and to ¾ Length
R Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull
S Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull (Bottom and Top: quadruple-riveted from $^{1}/_{5}$ Length to $^{3}/_{5}$ Length; treble-riveted amidships and to ¾ Length
T Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull
U Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length, then tapering to $^{12}/_{20}$ at ends of hull (Bottom: treble-riveted to $^{3}/_{5}$ Length, Top: treble-riveted to $^{3}/_{5}$ Length)
V Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends of hull (doubled for about 50ft at ends of Bridge)
W Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at ends of hull (Doubled for 60ft at ends of Bridge), hydraulically riveted. (Bottom and Top: treble-riveted to $^{3}/_{5}$ Length)
X Strake – in	$^{20}/_{20}$ for $^{2}/_{5}$ Length to $^{12}/_{20}$ at forecastle and poop. $^{20}/_{20}$ doubling to $^{2}/_{5}$ length then $^{18}/_{20}$. End plates of Bridge $^{22}/_{20}$. Double butt straps utilized at $^{15}/_{20}$ thickness, hydraulically riveted
Y Strake – out	$^{20}/_{20}$ for $^{2}/_{5}$ Length – end plates $^{16}/_{20}$ – $^{20}/_{20}$ doubling to ends of Bridge – $^{12}/_{20}$ in forecastle and poop. Double butt straps utilized at $^{15}/_{20}$ thickness. Hydraulically riveted. Bottom: treble riveted; Top: double-riveted


BILGE PLATING.
BILGE KEEL.

Above and right Fig. 7-19 **Bilge Keel** – Two views of the bilge keels; at top, a view from the ship's side looking inboard; at bottom, the bilge keel as viewed from beneath the turn of the bilge. *(H&W/Authors' collection)*



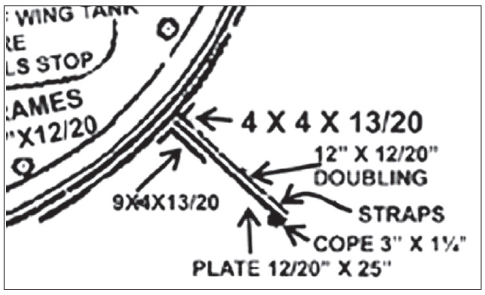

WING TANK
RE
LS STOP
AMES
"X12/20
4 X 4 X 13/20
12" X 12/20"
DOUBLING
STRAPS
9X4X13/20
COPE 3" X 1¼"
PLATE 12/20" X 25"

Fig. 7-20 **Section Through Bilge Keel**. *(Illustration by Bruce Beveridge based on original H&W Shell Plating Plan)*

Opposite Fig. 7-21 **Examples of Caulking Tools** – This figure illustrates the tools commonly employed in the caulking of plate seams in riveted steel and iron ship construction. While the examples depicted here came from an American source, both the tools and the methods employed were essentially the same on both sides of the Atlantic.

Tools 'A' and 'D' are examples of the machine-tool point which was called a 'straight splitter.' These were used for caulking plate laps and the edges of angles, and for the first operation in caulking butts. The cutting edges could be straight or slightly curved, and the projection of the face in a plane perpendicular to the length of the tool was ½in long and varied from ⅜in to ⅜in wide. In general, the projected width of the face of the tool selected was not greater than the thickness of the plating to be caulked; the ⅜in tool was used on very heavy plating only. In caulking overlapping edges, a line was traced on the caulking edge with the extreme point of the tool; the tool was then reversed and part of the metal which had loosened in the tracing operation was wedged under the caulking edge, the point of the tool being held toward the faying surfaces. These tools were also used for chipping square edges to a bevel to facilitate caulking. In caulking butts, a line was traced with the extreme point of the tool about ⅜in to 3⁄16in from the abutting edges on each plate; it was usually necessary to repeat this operation for plating of medium to heavy thickness.

Tools 'C' and 'E' are examples of rough tools, with 'carding' faces. These were used for finishing flush caulking, the heavier tool being used on mid to heavy plating. They were also used for caulking countersunk rivets where the rivet tool 'G' could not be used.

Tool 'B' is a 'bent splitter' and was used only in inconvenient places where it was impossible to use a straight tool as 'A' or 'D.'

Tools 'J' and 'K' were called 'fullers' and were sometimes used for laying up the metal in way of a beveled caulking edge and around liners, in order to provide a better bearing surface for the splitter tools used in caulking. These fullers were, however, seldom used.

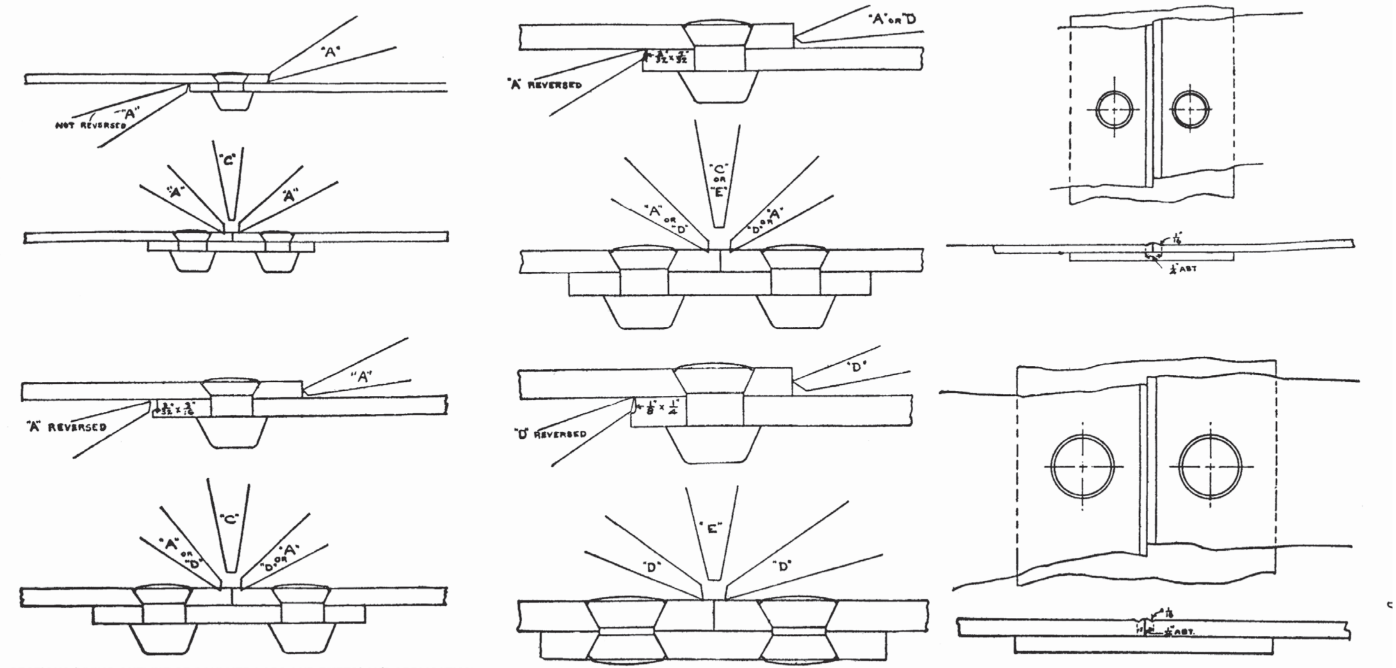
Tool 'H' – the 'smoothing tool' – was used mostly for removing gates, sprues and other projections from castings; it was also used in touching up leaky rivets, and was used in place of the heavy splitter, tool 'D', in caulking heavy plates, the narrow edge being used in splitting. A smooth tool with a face ¼in x ¼in was sometimes used in place of a splitter; tools 'A' and 'D', in caulking liners.

Tool 'G' – the 'rivet tool' – was used for caulking heads and points of countersunk rivets.

The 'grooved-bitt' caulking tool, 'F', was used for flush, non-watertight caulking where appearance was a consideration, such as the dust-tight caulking found in the passageways bordering the machinery and boiler casings. This tool was not efficient for watertight work.

The 'short' and 'long bend' caulking tools 'L' and 'M' could be made with either smooth or carding faces, and were used only in places where it was convenient to use the straight, smooth tool 'H' or straight, rough tools 'C' or 'E.'

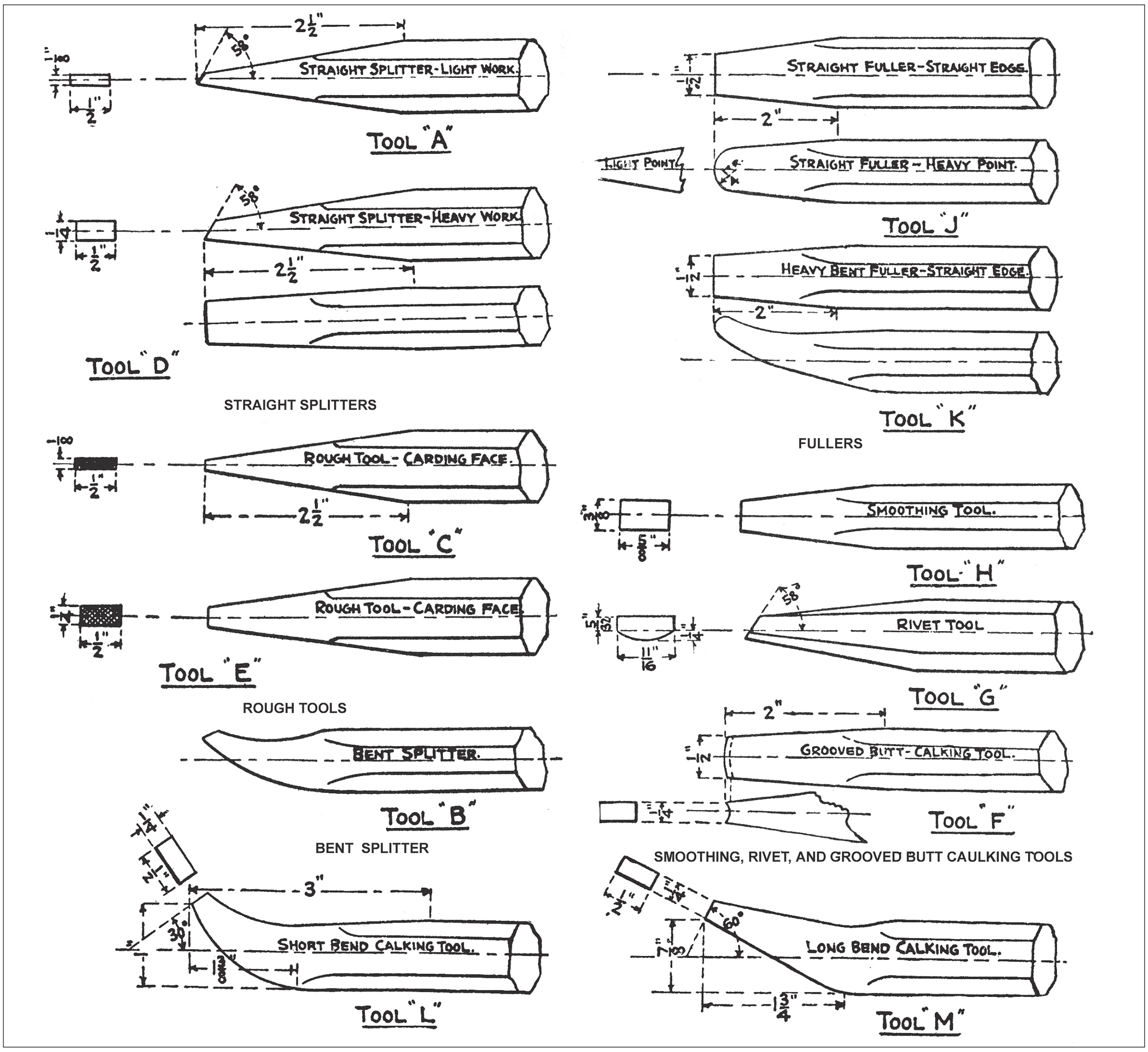
Below Fig. 7-22 **Caulking Techniques and Processes** – This figure serves to illustrate the manner in which the various types of plate seams were caulked, and how the tools shown in the preceding illustration were employed to achieve these results.

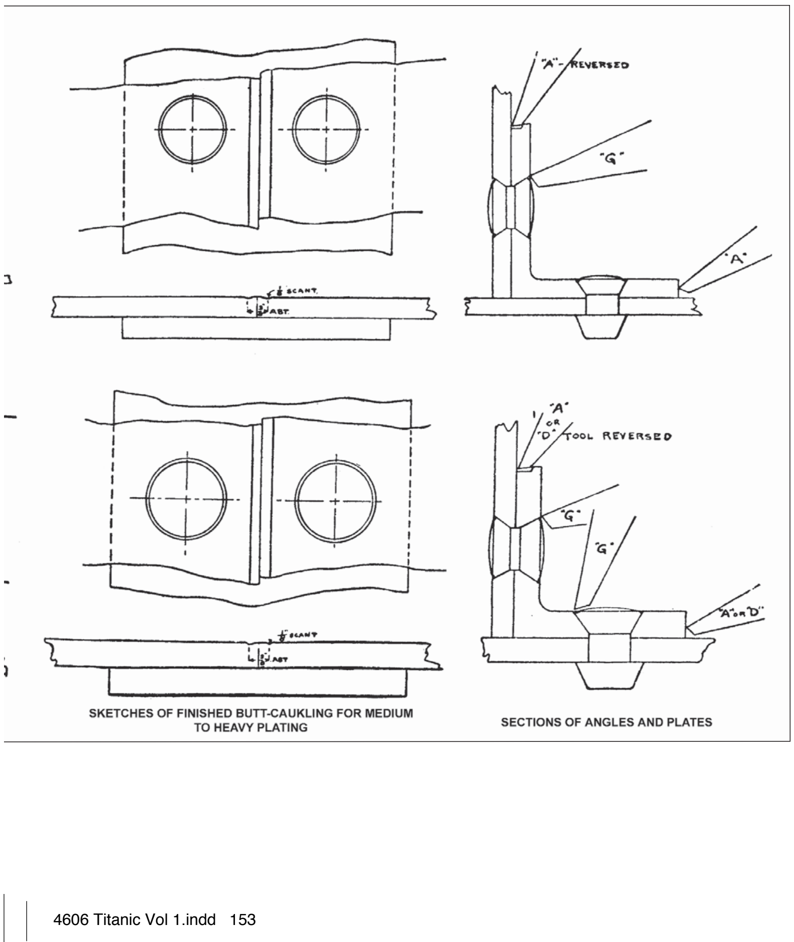


SECTIONS GIVING OUTLINE OF CAULKED LAPS AND BUTTS, AND APPLICATION OF TOOLS

MORE CAULKED LAPS AND BUTTS, AND APPLICATION OF TOOLS

SKETCHES OF FINISHED BUTT-CAULKING FOR LIGHT TO MEDIUM PLATING


STRAIGHT SPLITTER-LIGHT WORK.
2½"
58°
TOOL "A"
STRAIGHT SPLITTER-HEAVY WORK.
58°
2½"
TOOL "D"
STRAIGHT SPLITTERS
ROUGH TOOL - CARDING FACE.
2½"
TOOL "C"
ROUGH TOOL - CARDING FACE.
TOOL "E"
ROUGH TOOLS
BENT SPLITTER.
TOOL "B"
BENT SPLITTER
3"
30°
SHORT BEND CALKING TOOL.
TOOL "L"
STRAIGHT FULLER-STRAIGHT EDGE.
2"
LIGHT POINT
STRAIGHT FULLER - HEAVY POINT.
TOOL "J"
HEAVY BENT FULLER-STRAIGHT EDGE.
2"
TOOL "K"
FULLERS
SMOOTHING TOOL.
TOOL "H"
58°
RIVET TOOL
TOOL "G"
2"
GROOVED BUTT-CALKING TOOL.
TOOL "F"
SMOOTHING, RIVET, AND GROOVED BUTT CAULKING TOOLS
60°
LONG BEND CALKING TOOL.
1¾"
TOOL "M"


"A"-REVERSED
"G"
"A"
⅛" SCANT
"A" OR "D" TOOL REVERSED
"G"
"G"
"A" OR "D"
⅛" SCANT

SKETCHES OF FINISHED BUTT-CAULKING FOR MEDIUM TO HEAVY PLATING

SECTIONS OF ANGLES AND PLATES

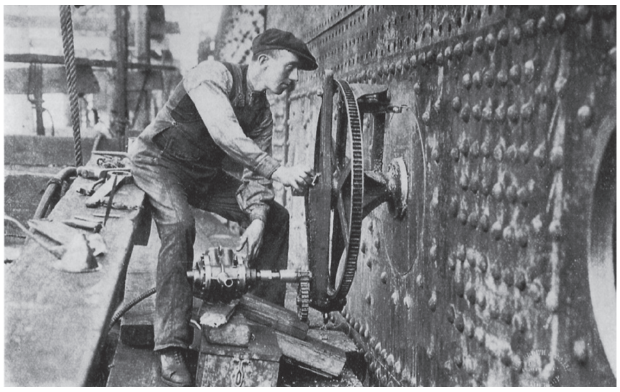


Fig. 7-23 **Pneumatic Porthole-Cutting Tool** – A pneumatic porthole-cutting tool in use during construction of the *Aquitania*. (Engineering/*Authors' collection)*

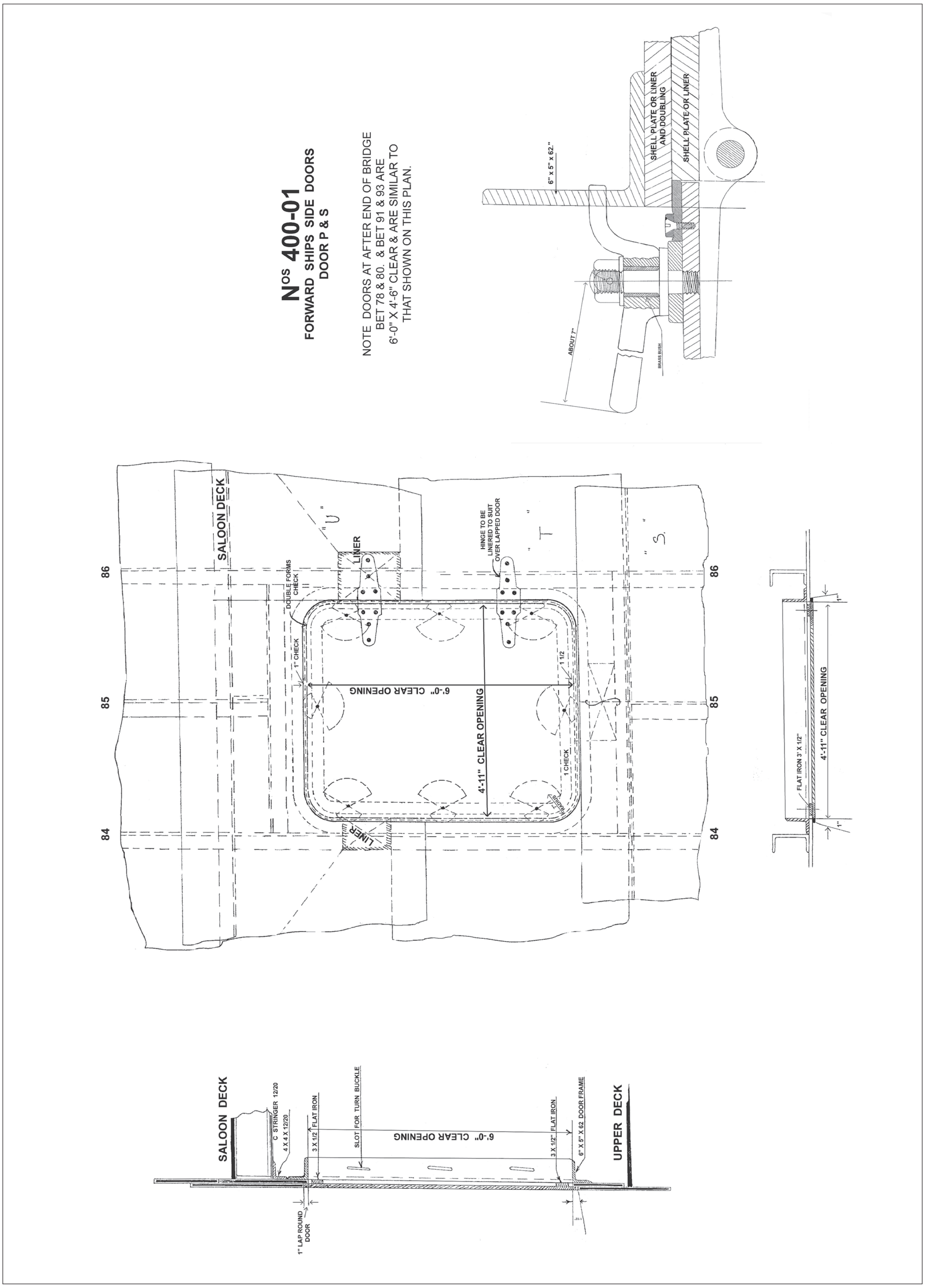

Nos 400-01
FORWARD SHIPS SIDE DOORS
DOOR P & S
NOTE DOORS AT AFTER END OF BRIDGE
BET 78 & 80. & BET 91 & 93 ARE
6'-0" X 4'-6" CLEAR & ARE SIMILAR TO
THAT SHOWN ON THIS PLAN.
6" x 5" x 62."
SHELL PLATE OR LINER AND DOUBLING
SHELL PLATE OR LINER
ABOUT 7"
BRASS BUSH
SALOON DECK
LINER
HINGE TO BE LINERED TO SUIT OVER LAPPED DOOR
DOUBLE FORMS CHECK
1" CHECK
6'-0" CLEAR OPENING
4'-11" CLEAR OPENING
1 1/2
1 CHECK
"U"
"T"
"S"
86
85
84
LINER
FLAT IRON 3" X 1/2"
4'-11" CLEAR OPENING
1"
1"
SALOON DECK
C STRINGER 12/20
4 X 4 X 12/20
3 X 1/2 FLAT IRON
SLOT FOR TURN BUCKLE
6'-0" CLEAR OPENING
3 X 1/2" FLAT IRON
6" X 5" X 62 DOOR FRAME
UPPER DECK
1" LAP ROUND DOOR

Fig. 7-24 **Ship's Forward Side Door** – One of the forward side doors of *Olympic* and *Titanic*. As this drawing shows a specific door, the details of the steelwork surrounding the door would be unique to its location, but the details of the structure of the door itself are representative of what would be found in the majority of the shell doors throughout the ship. As photographs of the completed ships show, this drawing depicts an earlier design for the door hinges which was replaced by a design that provided a much stronger attachment to the hull. *(Illustration by Bruce Beveridge based on original H&W Shell Door drawing)*

The bilge keels were placed to give the least possible resistance to propulsion and were kept as clear as possible from shell landings, tank-side riveting, etc. They were formed from steel plates measuring $^{12}/_{20}$in thick and 25in deep. These plates were attached to the hull by double angles, and were strengthened by doublers and straps where the end connections were made. Also, a 3in x 1¼in cope iron piece was fitted for strength along the outboard bottom edge of each bilge keel, forming a downward-facing bulb.

Caulking

The operation of caulking[1] the landing edges and butts of all joints in the steel work of a vessel was performed after the parts had been riveted together. The landings of plating and the edges of angle bars were treated alike, and in both cases the edges, if not already planed, were chipped square and smoothed preparatory to caulking. The caulking tool was a steel chisel with an obtuse edge. The object of caulking was to squeeze the faying surfaces together at the outside joint. This was done by cutting a slight groove in the chipped edge near the faying surface and, at the same time, setting the displaced material toward that surface. It was an absolute necessity that the surfaces be tightly fayed against each other

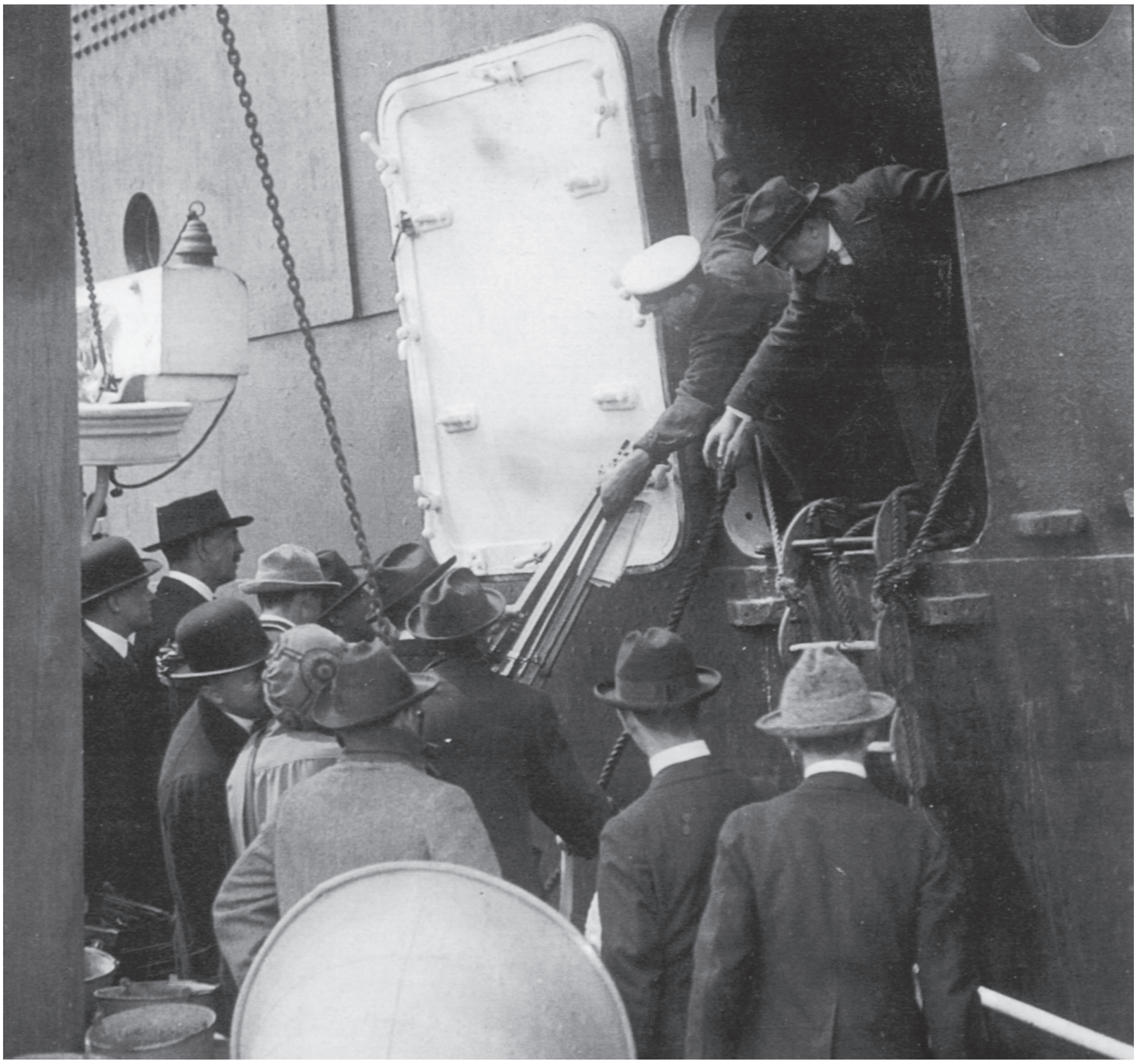


Fig. 7-25 **Forward Door Opened** – In this image of *Olympic*, the port-side E Deck door has been opened to allow members of the press to board the ship during a New York arrival.

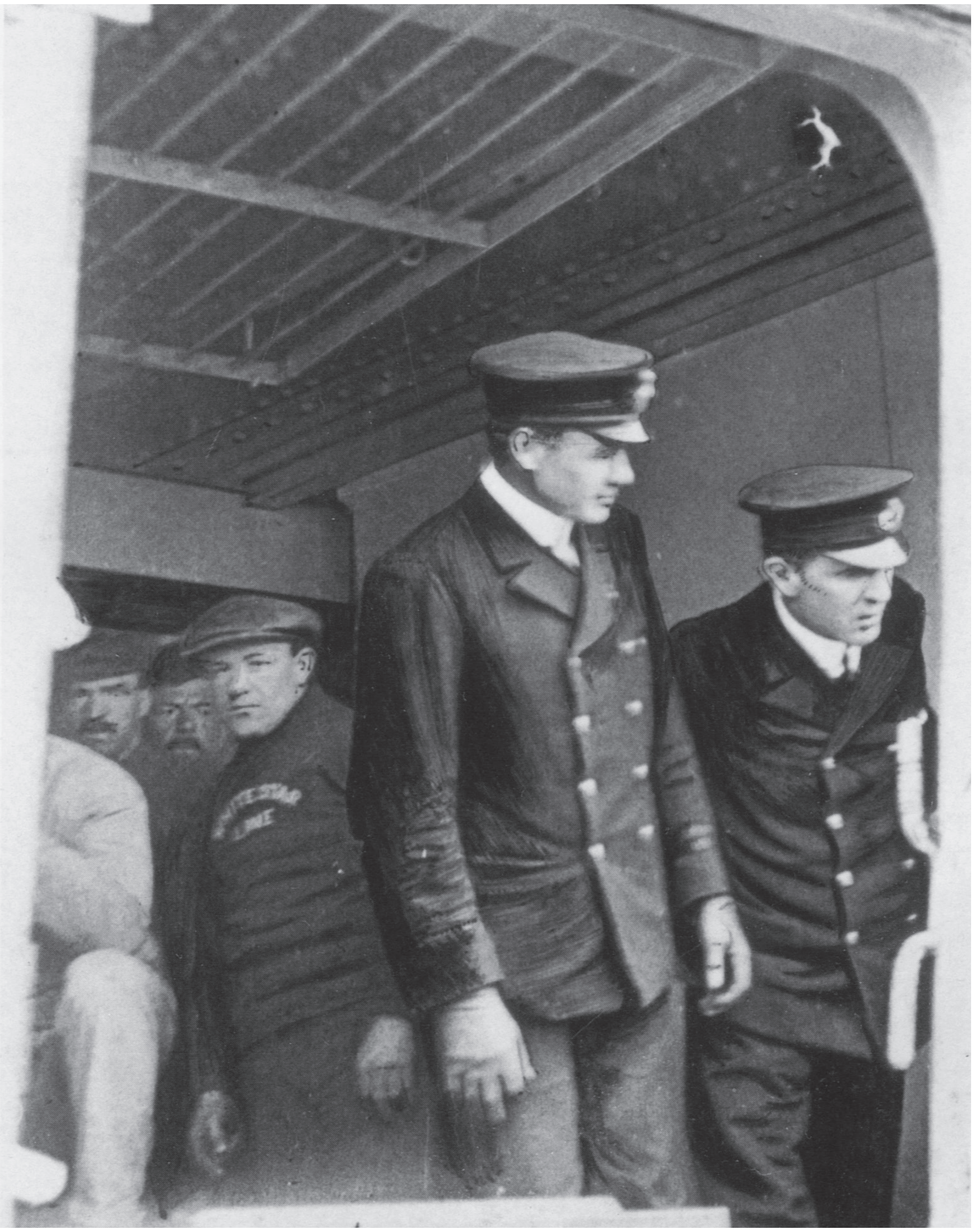
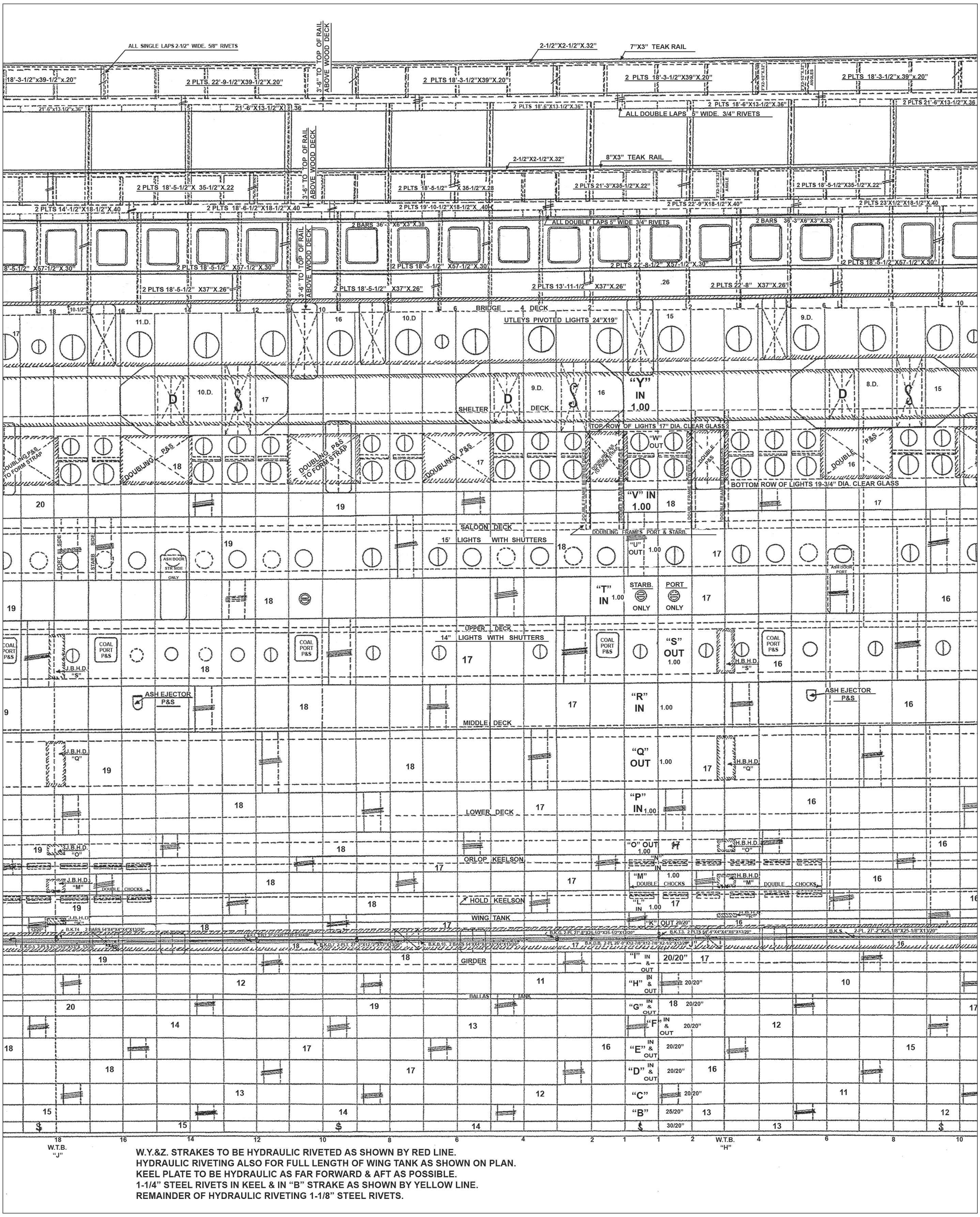


Fig. 7-26 **E Deck Door at Queenstown** – In this heavily retouched photograph taken at Queenstown from the departing tender, 2nd Officer Lightoller and 1st Officer Murdoch are seen through *Titanic*'s open starboard E Deck door forward. This is the same door detailed in the previous image. Note the hinged grating secured against the deck head. After the outer door had been closed and secured for sea, this grating would have been lowered and secured over the inboard side of the door. *(*Cork Examiner*/Authors' collection)*


ALL SINGLE LAPS 2-1/2" WIDE. 5/8" RIVETS
3'-6" TO TOP OF RAIL ABOVE WOOD DECK
2-1/2"X2-1/2"X.32"
7"X3" TEAK RAIL
18'-3-1/2"x39-1/2"x.20"
2 PLTS. 22'-9-1/2"X39-1/2"X.20"
2 PLTS 18'-3-1/2"X39"X.20"
2 PLTS 18'-3-1/2"X39"X.20"
2 PLTS 18'-3-1/2"x.39"x.20"
21'-6"X13-1/2"X.36
2 PLTS 18'-6"X13-1/2"X.36"
ALL DOUBLE LAPS 5" WIDE. 3/4" RIVETS
2 PLTS 18'-6"X13-1/2"X.36"
2 PLTS 21'-6"X13-1/2"X.36
8"X3" TEAK RAIL
2 PLTS 18'-5-1/2"X 35-1/2"X.22
2 PLTS 18'-5-1/2" X 35-1/2"X.28
2 PLTS 21'-3"X35-1/2"X.22"
2 PLTS 18'-5-1/2"X35-1/2"X.22"
2 PLTS 14'-1/2"X18-1/2"X.40
2 PLTS 18'-6-1/2"X18-1/2"X.40
2 PLTS 19'-10-1/2"X18-1/2"X.40
2 PLTS 22'-9"X18-1/2"X.40"
2 PLTS 23'X1/2"X18-1/2"X.40
2 BARS 36'-3"X6"X3"X.38
ALL DOUBLE LAPS 5" WIDE 3/4" RIVETS
2 BARS 36'-3"X6"X3"X.33"
2 PLTS 18'-5-1/2" X57-1/2"X.30"
2 PLTS 22'-8-1/2" X57-1/2"X.30"
2 PLTS 18'-5-1/2" X37"X.26"
2 PLTS 13'-11-1/2" X37"X.26"
2 PLTS 22'-8" X37"X.26"
BRIDGE DECK
UTLEYS PIVOTED LIGHTS 24"X19"
SHELTER DECK
"Y" IN 1.00
TOP ROW OF LIGHTS 17" DIA. CLEAR GLASS
"W" OUT
DOUBLING P&S TO FORM STRAP
BOTTOM ROW OF LIGHTS 19-3/4" DIA. CLEAR GLASS
"V" IN 1.00
SALOON DECK
15" LIGHTS WITH SHUTTERS
DOUBLING FRAMES PORT & STARB.
"U" OUT 1.00
ASH DOOR STR SIDE ONLY
ASH DOOR PORT
"T" IN 1.00
STARB. ONLY
PORT ONLY
UPPER DECK
14" LIGHTS WITH SHUTTERS
COAL PORT P&S
"S" OUT 1.00
H.B.H.D. "S"
J.B.H.D. "S"
ASH EJECTOR P&S
"R" IN 1.00
MIDDLE DECK
J.B.H.D. "Q"
"Q" OUT 1.00
H.B.H.D. "Q"
"P" IN 1.00
LOWER DECK
J.B.H.D. "O"
"O" OUT 1.00
H.B.H.D. "O"
ORLOP KEELSON
J.B.H.D. "M"
"M" 1.00
DOUBLE CHOCKS
H.B.H.D. "M"
HOLD KEELSON
"L" IN 1.00
WING TANK
"K" OUT 20/20"
GIRDER
"I" IN & OUT 20/20"
"H" IN & OUT 20/20"
BALLAST TANK
"G" IN & OUT 20/20"
"F" IN & OUT 20/20"
"E" IN & OUT 20/20"
"D" IN & OUT 20/20"
"C" 20/20"
"B" 25/20"
30/20"
W.T.B. "J"
W.T.B. "H"

W.Y.&Z. STRAKES TO BE HYDRAULIC RIVETED AS SHOWN BY RED LINE.
HYDRAULIC RIVETING ALSO FOR FULL LENGTH OF WING TANK AS SHOWN ON PLAN.
KEEL PLATE TO BE HYDRAULIC AS FAR FORWARD & AFT AS POSSIBLE.
1-1/4" STEEL RIVETS IN KEEL & IN "B" STRAKE AS SHOWN BY YELLOW LINE.
REMAINDER OF HYDRAULIC RIVETING 1-1/8" STEEL RIVETS.

Fig. 7-27 **400-01 Shell Plating Plan** – A portion of the starboard profile shell plating plan for *Olympic* and *Titanic*. This drawing shows both ships 'as launched,' hence the configuration of the B Deck windows. The amidships area of the profile view is where some of the more generalized notes are located, such as the size of sidelights and the heights of bulwarks, etc. The letters which identify the strakes are called out here, too, and also at the ¾-length amidships markers towards either end of the profile. *(Illustration by Bruce Beveridge based on the original H&W Shell Plating Plan)* with proper rivet spacing and installation to ensure the effectiveness of caulking.

To determine if the shell plating adjacent to the fore-and-aft water tanks was watertight, each section was flooded with water and the outside checked for leaks. In order that the flooded area could be emptied easily, a drain hole was drilled in the lowest part of the area. The hole was tapped and then plugged with a suitable bolt. To remove the water after testing, the bolt was partially unscrewed, a piece of string was wound onto it, and, standing well clear, the men pulled the string to unwind and remove the bolt, allowing the water to drain.

Shell openings and doors

The various openings required in the shell plating for sidelights, shell doors and coaling ports, sea chests and other through-hull openings were made after the shell plates were installed and the openings doubled for strength. Portholes were cut in with a pneumatically-powered cutting device.

Doors provided for the loading of coal were secured by means of strongbacks and turnbuckles in order to make a watertight fit. The outsides of the doors were made flush with the shell plating by means of doublings where required.

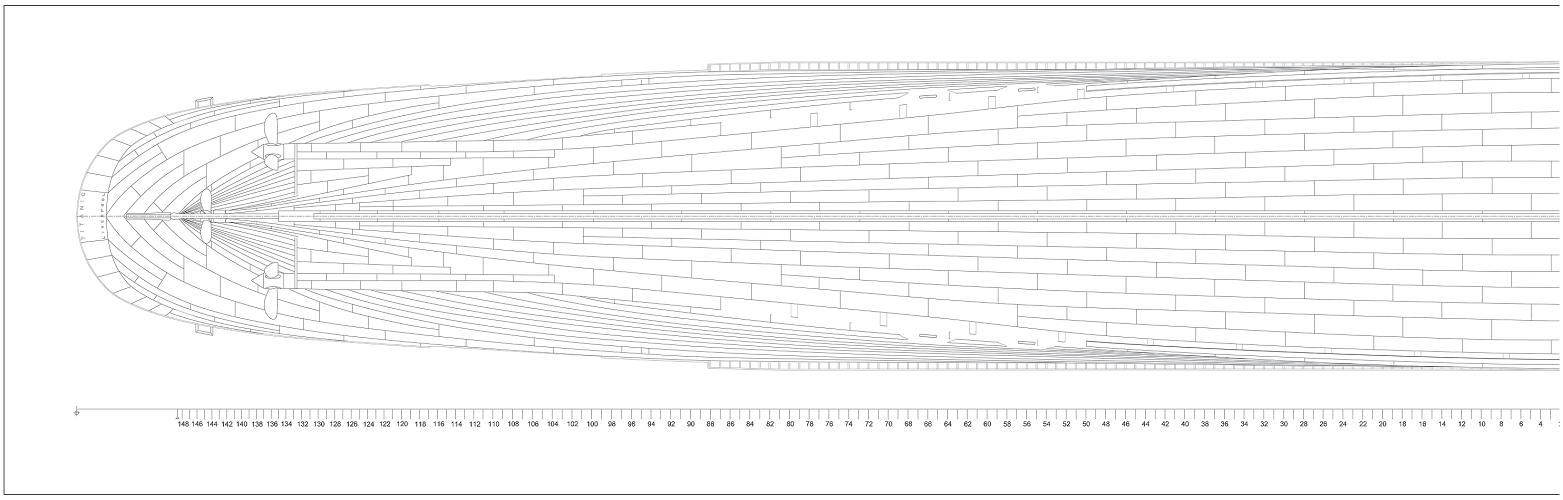


Fig. 7-28 **View From Beneath Hull** – This plan view shows an ordinary parallel projection of the shell plates of the bottom of the hull. This is an area of the ship that is often asked about because it cannot be seen completely in photos for obvious reasons. Though not immediately apparent to someone not familiar with naval architectural drafting practices, the bottom shell plating is, in fact, shown on the H&W shell plating plan; however, that drawing depicts these strakes in a 'compressed' format – the opposite of a 'shell expansion.' *(Illustration by Bob Read)*

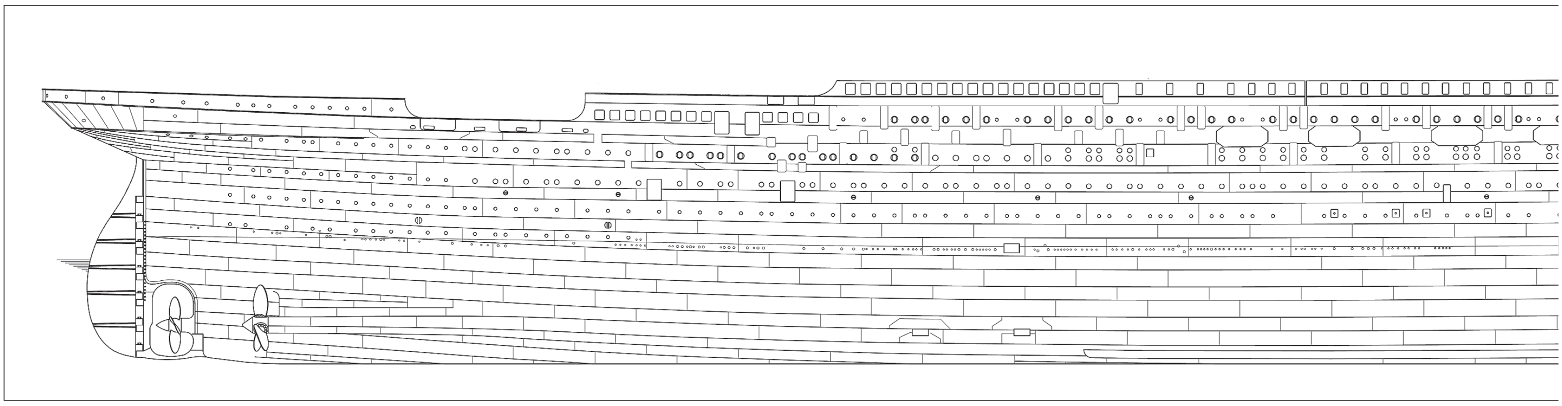
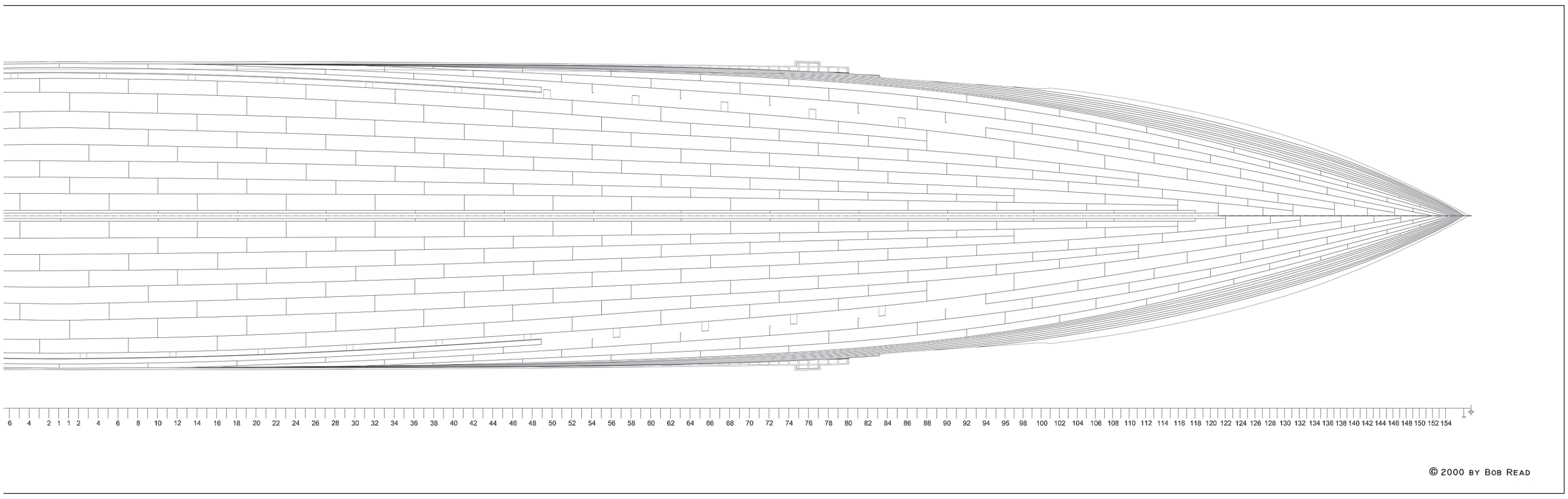


Fig. 7-29 **Starboard Profile** – *Titanic*'s starboard profile showing a true projection of the shell plates. *(From the Hahn Titanic Plans/ Illustration by Robert Hahn)*

Passenger and crew gangway doors were provided with internal protective gratings; generally, these were swing-down gates with plain round spills and were designed to be hinged up and stowed against the deckhead when not guarding the openings. Hinged or drop-down gates were required by the Board of Trade for all shell doors which could be left open at any time for ventilation purposes, and over all shell doors in the passenger areas. While leaving these doors open may not have been done frequently on the *Olympic*-class ships in North Atlantic service, and certainly not on *Titanic* in April, it *was* a frequent practice in hot-weather climates – for example, on P&O ships south of Suez while underway, when the outer shell doors above the bulkhead deck and at both ends of the vessel were often triced open to help deal with the tropical heat. Combined with the ship's headway, this caused a strong natural draft along the passageways and up all of the stairwells. Those gates, both at sea and while in port or riding at anchor, prevented the unwary from falling into the water.

A notable exception to the utilitarian swing-down gates were the protective gates which covered the First Class passenger gangway doors on D Deck. These doors, which opened into the vestibules on either side


6 4 2 1 1 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110 112 114 116 118 120 122 124 126 128 130 132 134 136 138 140 142 144 146 148 150 152 154

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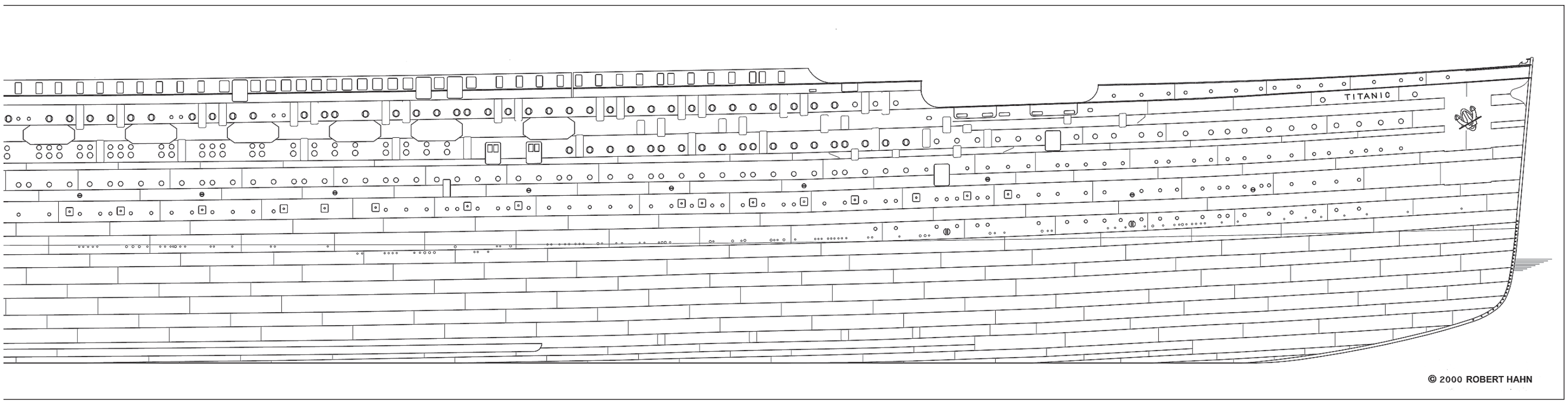

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of the First Class Reception Room, were each fitted with a pair of full-height, vertically-hinged ornamental wrought-iron gates designed to harmonize with the surrounding décor. Vertically hinged gates are shown on *Olympic*'s General Arrangement plans and the Emergency Station plan, and are visible in film footage shot by director James Cameron during his explorations of the interior of the wreck.

Notes

1. The term 'caulking', as described herein, should not be confused with the process of caulking that involves the sealing of a joint by the application of a watertight substance to or within the joint.

Chapter 8

Steel Decking; Wood Sheathing; Waterways and Scuppers

Camber

A ship's decks are horizontal platforms which extend across the hull at various heights above the inner bottom. The decks within the hull are bounded by the shell plating and are connected to the beams and to trunk and hatch openings. The beams and plating are arched upward; this arching is referred to as camber, or 'round of beam'. Camber is built into a deck so any water on it will run to the scuppers and drain overboard. Camber is usually measured in inches or fractions of inches per each foot of the breadth of a ship. *Titanic*'s decks had an overall athwartship camber of 3in. Technically speaking, her decks had a camber of 3in in 92ft, meaning that on a ship having a breadth overall of 92ft, the deck would be 3in higher at the centerline than at the sides when measured at the broadest point. The amount of camber and the decks on which it was employed varied with the particular builder. In some ships, the camber was not continued on decks below the weather decks, however on *Titanic*, all of her decks had camber.

Steel deck construction

Beneath steel decks the preferred practice was to fit beams to every frame, and where the plating of the decks was thin, this was imperative. Thin plating, when not supported by closely spaced beams, was liable to sag, or 'fall hollow', in the spaces between the beams. In small vessels, the deck beams were uniformly either plain or bulb angles. In large passenger steamers, channel bar was employed for the deck beams throughout much

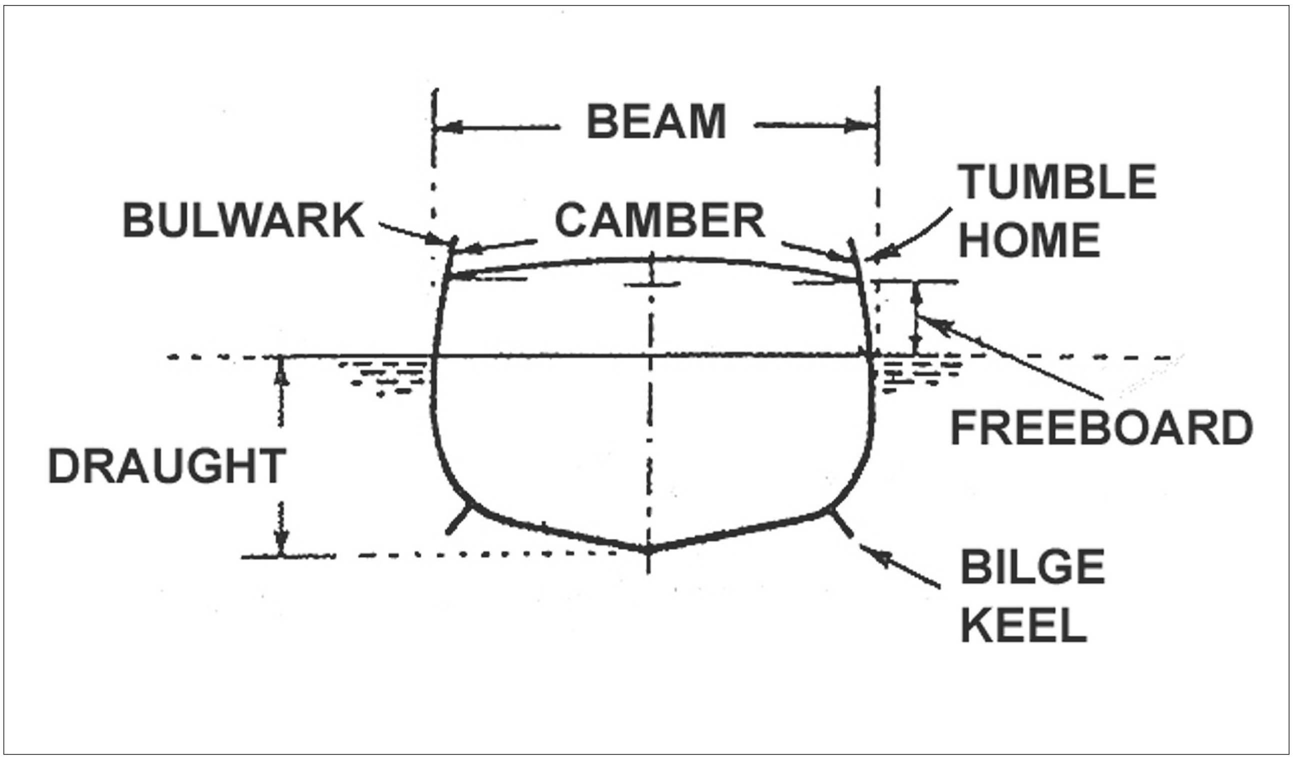


Fig. 8-1 **Camber**. An illustration of the term 'camber', along with some other terms relating to the hull.

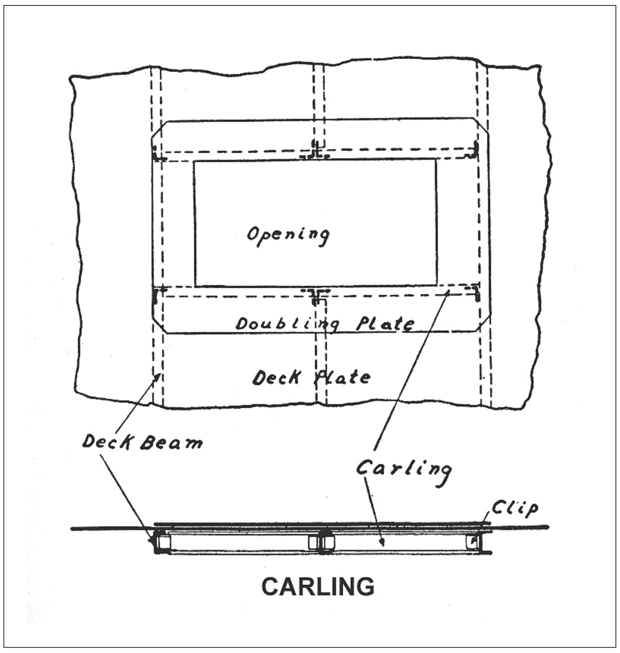

Opening
Doubling Plate
Deck Plate
Deck Beam
Carling
Clip
CARLING

Fig. 8-2 **Carlings Around a Deck Opening** – This drawing illustrates the typical arrangement of carlings on either side of a small deck opening.

or all of the hull, with bulb angle being used in the lighter construction of the superstructure.

As previously described, from B Deck on down, *Titanic*'s decks were supported by transverse channel beams 9in in depth, except in specific areas such as the decks within the hold spaces, where the depth was increased to 10in. Except in way of the cargo hatches, boiler and machinery casings and other large openings, the deck beams extended clear across the ship, the ends being attached to the frames at the outer shell. When openings through the deck were long enough to require the interrupting of deck beams, the interrupted beams were riveted to a fore-and-aft frame, called a 'hatch side girder' or 'carling', which extended between uncut beams and transmitted the loads from the cut beams to the adjacent uncut ones.

Brackets, or 'knees', connected the deck beams to frames, while along their width, the deck beams were supported from beneath on longitudinal girders which were, in turn, supported by pillars and columns; all of these supporting elements are dealt with in greater detail in Chapter 4 of this volume.

The decks forming the superstructure were not designed to play any part in strengthening the ship. However, they were built to be rigid and to resist racking forces when under the strain of high seas; to aid in the latter, these decks were fitted with expansion joints fore and aft to accommodate shifting. Under the steel decks of the superstructure, the transverse beams were generally of bulb angle, 7in deep on the Promenade Deck, and 6in deep on the Boat Deck. The size and form of these beams were altered locally as the design dictated, such as on the Boat Deck, where alternate roof beams over the Verandah and Palm Courts were made from 5in channel, or the deck beams above the deckhouses on the Boat Deck which were 4in x 2½in bulb angles.

Apart from the beams, the most important structural item in a steel deck was the stringer plate, or 'deck stringer', the thickened strake of plating that ran along the outer

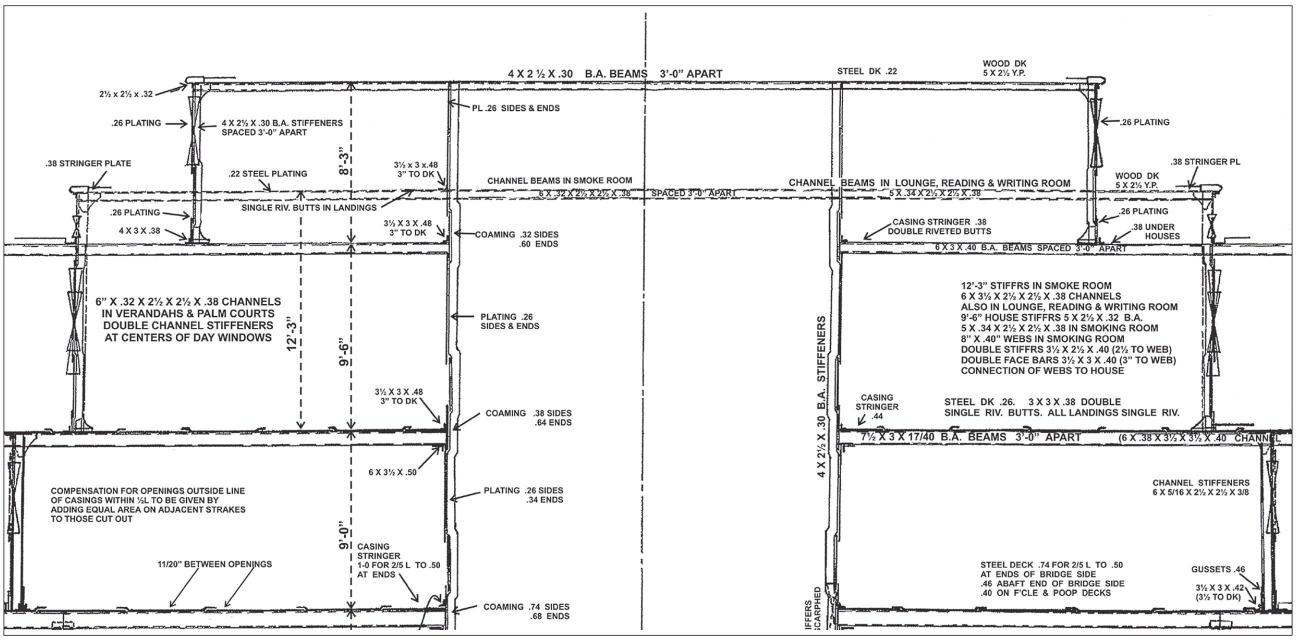

4 X 2 ½ X .30 B.A. BEAMS 3'-0" APART
STEEL DK .22
WOOD DK 5 X 2½ Y.P.
2½ x 2½ x .32
.26 PLATING
4 X 2½ X .30 B.A. STIFFENERS SPACED 3'-0" APART
PL .26 SIDES & ENDS
.26 PLATING
.38 STRINGER PLATE
.22 STEEL PLATING
8'-3"
3½ x 3 x.48 3" TO DK
CHANNEL BEAMS IN SMOKE ROOM
6 X .32 X 2½ X 2½ X .38
SPACED 3'-0" APART
CHANNEL BEAMS IN LOUNGE, READING & WRITING ROOM
5 X .34 X 2½ X 2½ X .38
.38 STRINGER PL
WOOD DK 5 X 2½ Y.P.
SINGLE RIV. BUTTS IN LANDINGS
.26 PLATING
4 X 3 X .38
3½ X 3 X .48 3" TO DK
COAMING .32 SIDES .60 ENDS
CASING STRINGER .38 DOUBLE RIVETED BUTTS
.26 PLATING
.38 UNDER HOUSES
6 X 3 X .40 B.A. BEAMS SPACED 3'-0" APART
6" X .32 X 2½ X 2½ X .38 CHANNELS IN VERANDAHS & PALM COURTS DOUBLE CHANNEL STIFFENERS AT CENTERS OF DAY WINDOWS
12'-3"
9'-6"
PLATING .26 SIDES & ENDS
12'-3" STIFFRS IN SMOKE ROOM
6 X 3½ X 2½ X 2½ X .38 CHANNELS
ALSO IN LOUNGE, READING & WRITING ROOM
9'-6" HOUSE STIFFRS 5 X 2½ X .32 B.A.
5 X .34 X 2½ X 2½ X .38 IN SMOKING ROOM
8" X .40" WEBS IN SMOKING ROOM
DOUBLE STIFFRS 3½ X 2½ X .40 (2½ TO WEB)
DOUBLE FACE BARS 3½ X 3 X .40 (3" TO WEB)
CONNECTION OF WEBS TO HOUSE
4 X 2½ X .30 B.A. STIFFENERS
CASING STRINGER .44
STEEL DK .26. 3 X 3 X .38 DOUBLE SINGLE RIV. BUTTS. ALL LANDINGS SINGLE RIV.
3½ X 3 X .48 3" TO DK
COAMING .38 SIDES .64 ENDS
7½ X 3 X 17/40 B.A. BEAMS 3'-0" APART
(6 X .38 X 3½ X 3½ X .40 CHANNEL
6 X 3½ X .50
COMPENSATION FOR OPENINGS OUTSIDE LINE OF CASINGS WITHIN ½L TO BE GIVEN BY ADDING EQUAL AREA ON ADJACENT STRAKES TO THOSE CUT OUT
PLATING .26 SIDES .34 ENDS
CHANNEL STIFFENERS 6 X 5/16 X 2½ X 2½ X 3/8
9'-0"
CASING STRINGER 1-0 FOR 2/5 L TO .50 AT ENDS
11/20" BETWEEN OPENINGS
STEEL DECK .74 FOR 2/5 L TO .50 AT ENDS OF BRIDGE SIDE .46 ABAFT END OF BRIDGE SIDE .40 ON F'CLE & POOP DECKS
GUSSETS .46
3½ X 3 X .42 (3½ TO DK)
COAMING .74 SIDES .68 ENDS
IFFERS SCARPHED

Fig. 8-3 **Superstructure Decks at Inboard Ends** – This detail from the midship section shows the general scantlings and structural details of deckhouse and inboard ends of the decks of the superstructure. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

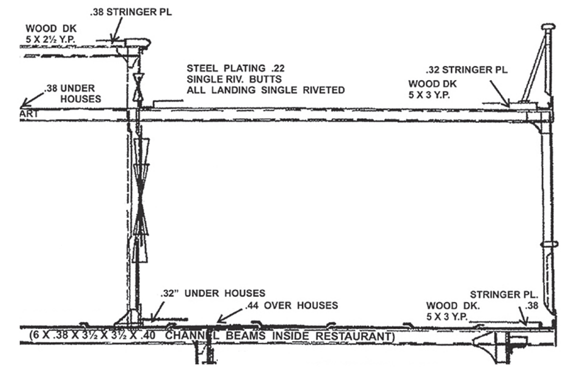

.38 STRINGER PL
WOOD DK
5 X 2½ Y.P.
STEEL PLATING .22
SINGLE RIV. BUTTS
ALL LANDING SINGLE RIVETED
.32 STRINGER PL
WOOD DK
5 X 3 Y.P.
.38 UNDER
HOUSES
ART
.32" UNDER HOUSES
.44 OVER HOUSES
STRINGER PL.
WOOD DK.
5 X 3 Y.P.
.38
(6 X .38 X 3½ X 3½ X .40 CHANNEL BEAMS INSIDE RESTAURANT)

Fig. 8-4 **Deck Structure at Outboard Ends** – This detail taken from the half section shows the common structural features of the decks at the outboard end. Note the 'stringer plate,' which is the outermost strake of the deck plating. *(Illustration by Bruce Beveridge based on original H&W Midship Section)*

edges of each deck. This plate was always at least 25 per cent thicker than the rest of the deck plates, and along the top edge of the hull, it was generally made as thick as the plates of the adjoining sheer strakes of the shell. In the largest ships, a second strake of increased thickness – designated the 'inner stringer plate' or 'inner deck stringer' – was laid down inboard of the stringer plate. On the *Olympic*-class ships, an inner stringer plate was fitted along both sides for the entire length of the Bridge Deck (B), and for about three-quarters of the length of the ship on the Shelter Deck (C) and Saloon Deck (D). Where these double stringer plates were fitted, on the drawings they were marked as the 'outer stringer' and 'inner stringer'.

In order to attach the deck stringer to the shell plating, it was common practice in large vessels to make the connection by means of double angles. This was especially necessary in the upper decks in large vessels having several decks. Where the frames terminated at

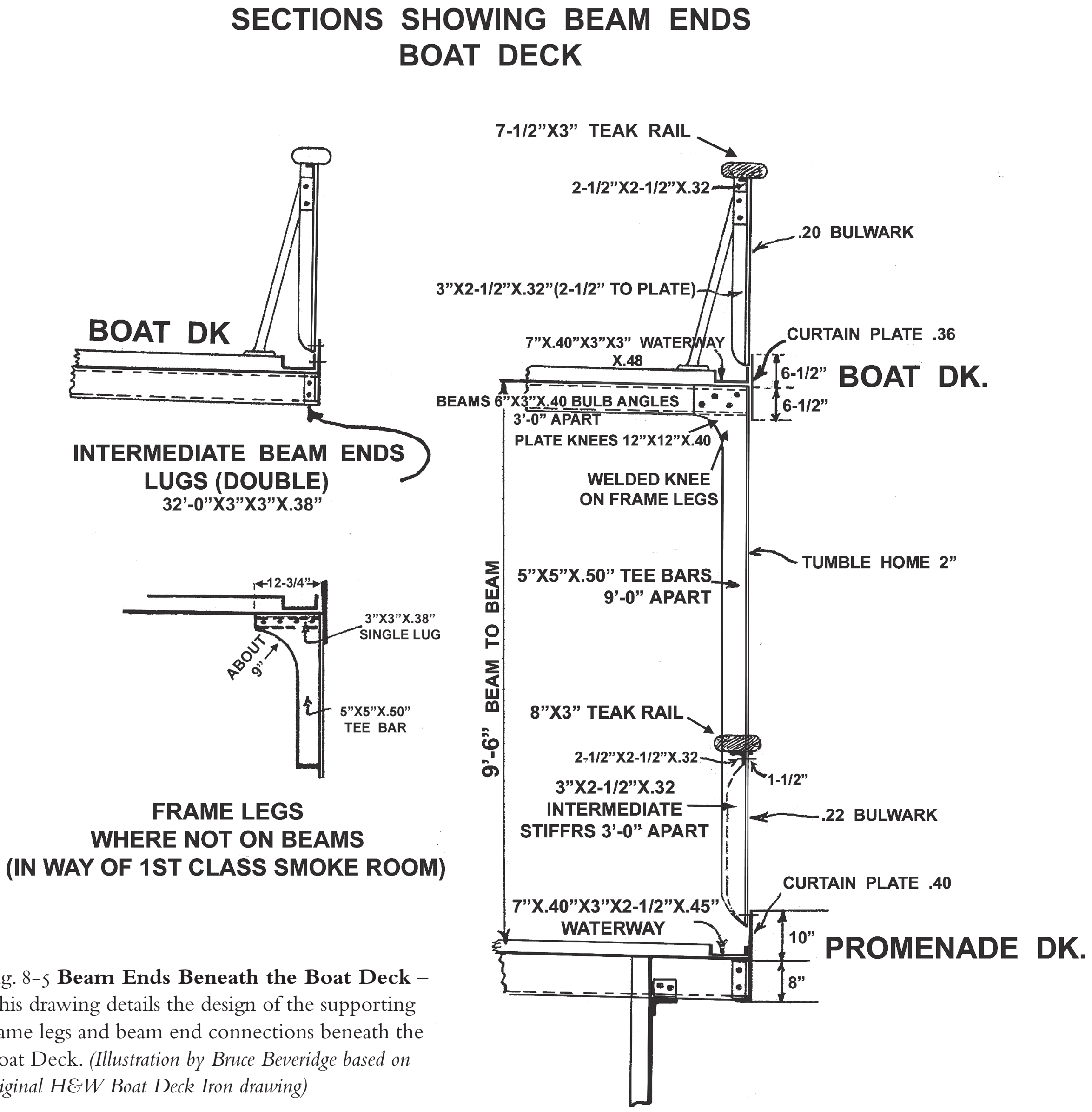

SECTIONS SHOWING BEAM ENDS
BOAT DECK
7-1/2"X3" TEAK RAIL
2-1/2"X2-1/2"X.32
.20 BULWARK
3"X2-1/2"X.32"(2-1/2" TO PLATE)
BOAT DK
7"X.40"X3"X3" WATERWAY
X.48
CURTAIN PLATE .36
6-1/2"
BOAT DK.
6-1/2"
BEAMS 6"X3"X.40 BULB ANGLES
3'-0" APART
PLATE KNEES 12"X12"X.40
INTERMEDIATE BEAM ENDS
LUGS (DOUBLE)
32'-0"X3"X3"X.38"
WELDED KNEE
ON FRAME LEGS
TUMBLE HOME 2"
12-3/4"
5"X5"X.50" TEE BARS
9'-0" APART
3"X3"X.38"
SINGLE LUG
ABOUT
9"
9'-6" BEAM TO BEAM
5"X5"X.50"
TEE BAR
8"X3" TEAK RAIL
2-1/2"X2-1/2"X.32
1-1/2"
3"X2-1/2"X.32
INTERMEDIATE
STIFFRS 3'-0" APART
.22 BULWARK
FRAME LEGS
WHERE NOT ON BEAMS
(IN WAY OF 1ST CLASS SMOKE ROOM)
CURTAIN PLATE .40
7"X.40"X3"X2-1/2"X.45"
WATERWAY
10"
PROMENADE DK.
8"

Fig. 8-5 **Beam Ends Beneath the Boat Deck** – This drawing details the design of the supporting frame legs and beam end connections beneath the Boat Deck. *(Illustration by Bruce Beveridge based on original H&W Boat Deck Iron drawing)*

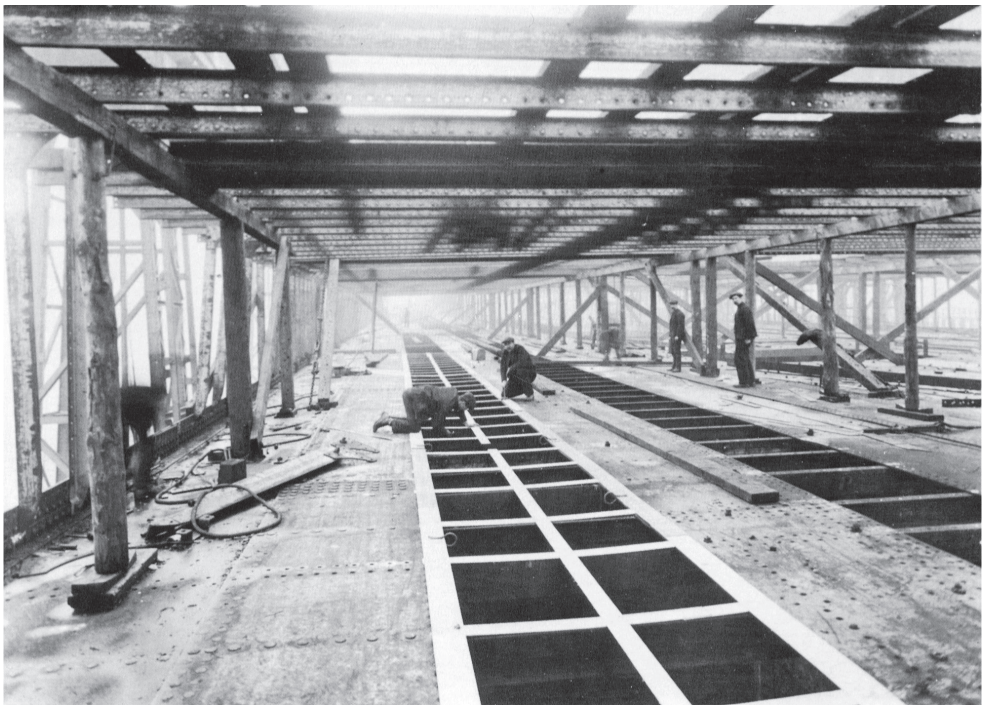


Fig. 8-6 **Bridge Deck (B) – *Britannic*** – In this image of *Britannic* under construction, temporary wooden staging supports the beams of A Deck above, while construction continues on B Deck. To the left, the blurred image of a Riveter can be seen as he works to attach the outboard frame legs to the edge of the shell plating. In the center of the photograph, two Shipwrights are seen constructing the wooden templates which will be used to 'lift' the plates for this strake. *(H&W/Authors' collection)*

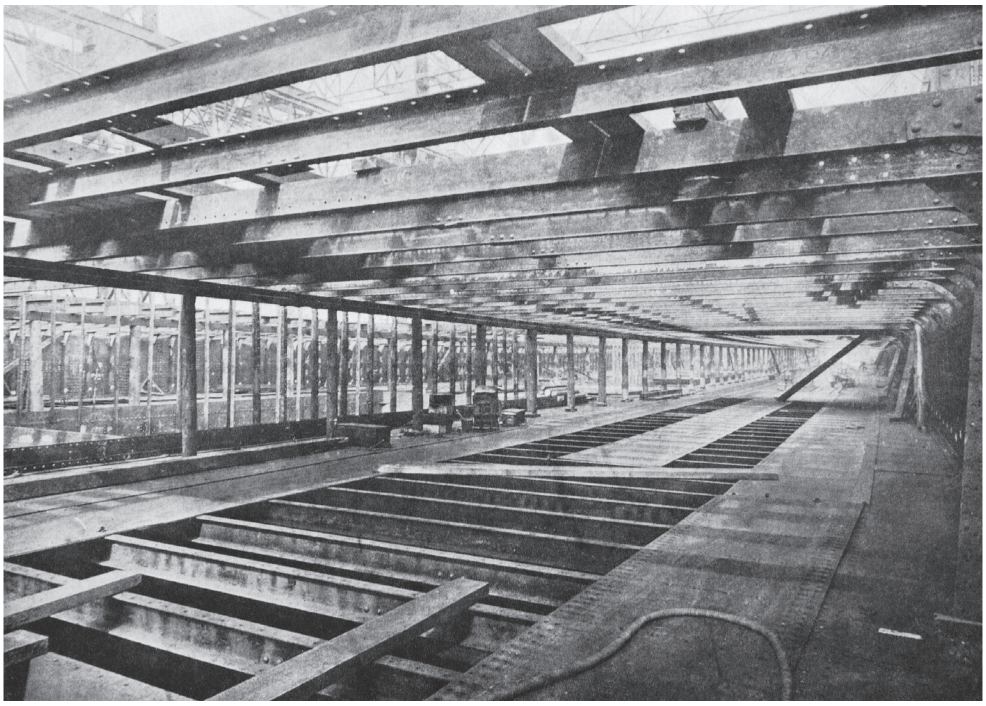


Fig. 8-7 **Shelter Deck (C) on *Olympic*, Looking Aft** – *Olympic*'s Shelter Deck (C) is seen here in the course of plating. The joggling of the plate landings is clearly visible. *(*Engineering*/Authors' collection)*

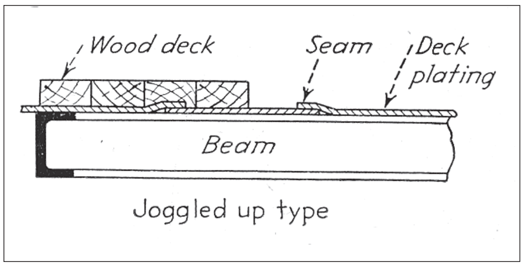


Fig. 8-8 **Joggled Deck Plating**.

the top-deck stringer plate, as was the case with the Bridge Deck (B) amidships, a single, continuous heavy angle called a gunwale bar or 'stringer bar' connected the deck stringer to the shell. On the decks beneath the Bridge Deck (B), where the frames passed through the deck stringers, angles arranged intercostally between the frames, called shell lugs or 'stringer chocks', connected the outer edges of the deck stringers to the shell plating. On these decks, the continuous angle stringer bar was laid inboard of, and immediately adjacent to, the frames and connected the

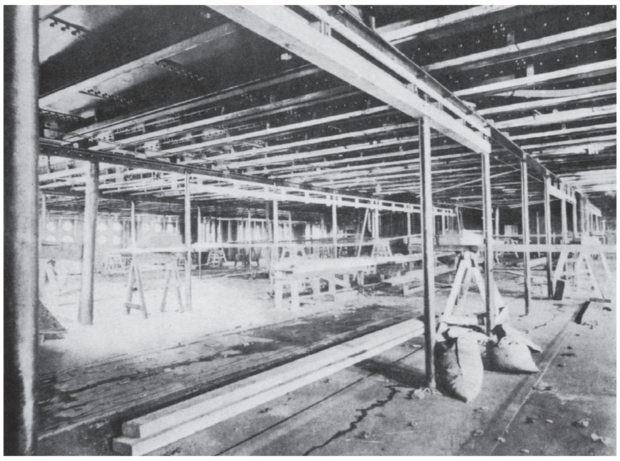


Fig. 8-9 **First Class Dining Saloon – *Olympic*** – In this view, the steel structure has advanced sufficiently to allow carpenters to begin installation of the wood ferrings to which the interior joinery will be attached. *(*Engineering*/Authors' collection)*

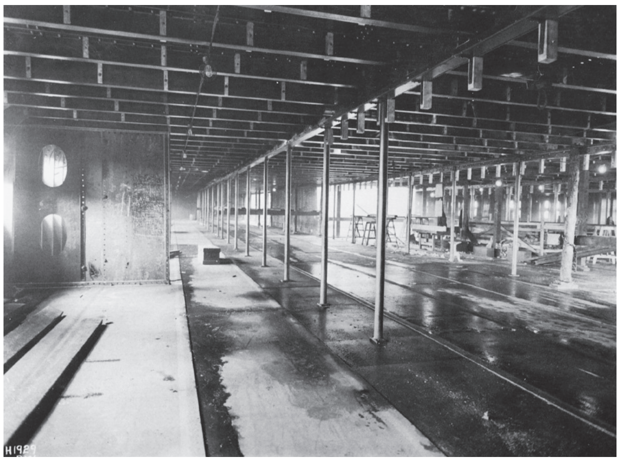


Fig. 8-10 **First Class Dining Saloon – *Britannic*** – This image shows *Britannic*'s First Class Dining Saloon at nearly the same point in progress as in the previous *Olympic* photograph. The joggling of the deck plates is easily distinguished in this view. A large web plate, pierced with oval lightening holes, appears at the left of the picture. *(H&W/Authors' collection)*

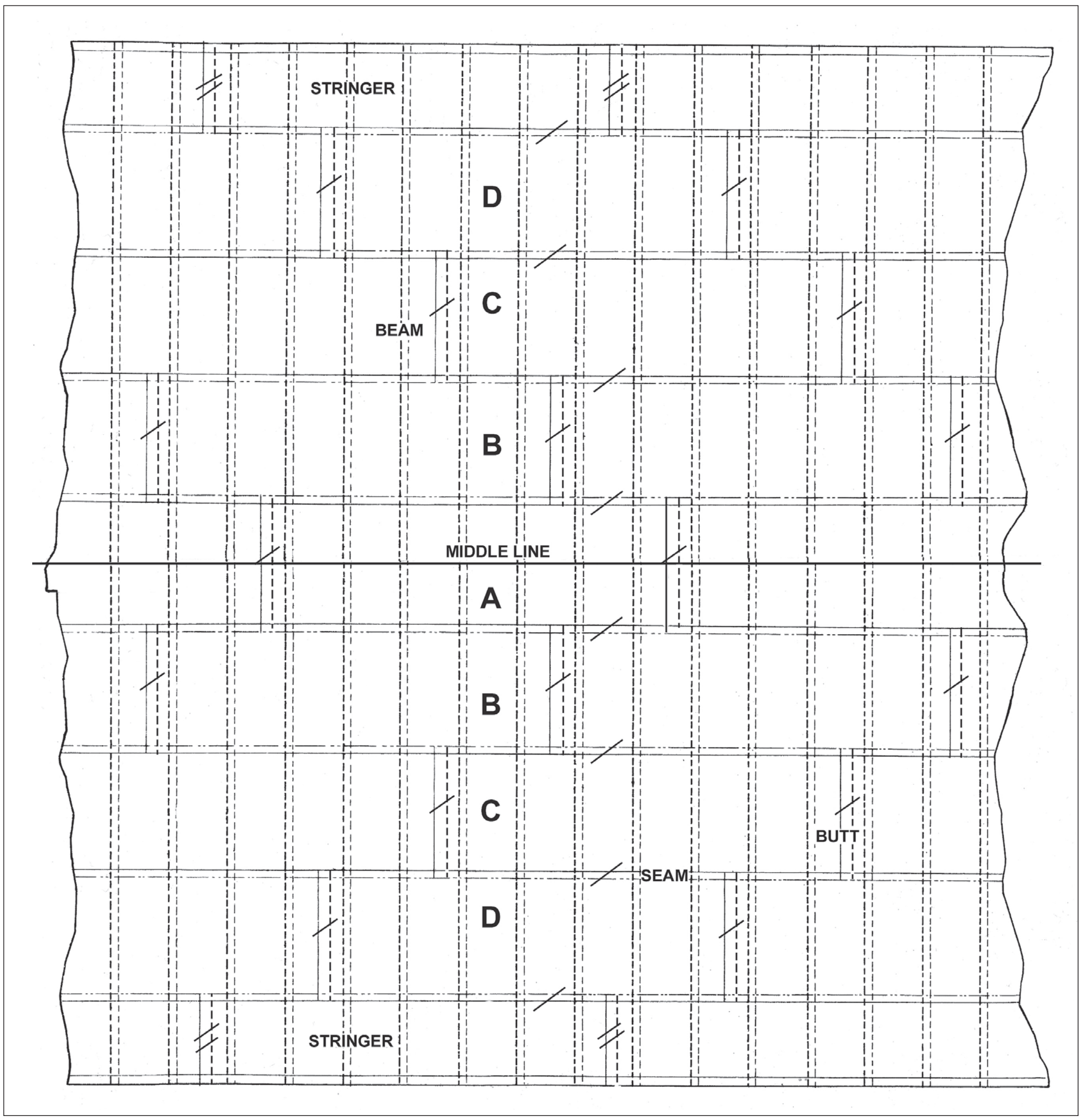


Fig. 8-11 **Deck Plating Drawing** – This illustration provides a generalized example of the sort of markings which appear on a deck plating drawing. The single slashes indicate single rows of rivets, double slashes a double row of rivets, etc., while the letters identify the strakes of plates.

deck stringers to the inboard flanges of the channel frames and reverse angles. The outboard edges of the Boat Deck and A Deck were supported at the sides of the ship by steel T- and angle-bar stanchions referred to as 'frame legs;' because of the reduced stresses placed upon the structures situated above the main strength deck, a savings in topside weight was achieved by increasing the interval between these supports to every third frame.

The steel deck plating, like the shell plating, was fitted in wide fore-and-aft strakes, the plates being rectangular in form amidships and tapering at the ends of the vessel to conform to the curvature of the hull. The width of the deck plates varied as well as the length. Depending upon their deck and location, the deck seams (the longitudinal side joints of the plating) were double- or single-riveted while the deck butts (the transverse end joints) were single-, double-, treble- or quadruple-riveted. The connection of the deck plates to the beams in nearly all cases was single-riveted.

The steel deck plating of *Titanic* was both joggled and attached in the in-and-out system. Joggling the landing edges with this system of plating allowed the plates within all strakes to rest directly on the beams, which avoided the use of liners. In addition to obviating the difficulties associated with three-ply riveting, the omission of plate liners allowed the decks to be lighter, a benefit which was of particular importance with structures located well above the waterline.

The longitudinal rows of deck plates were lettered for reference on the deck iron plans, starting from A at the centerline of the ship and progressing to B, C, etc. to both port and starboard through the alphabet, just as was done with the strakes of the shell plating, where the keel strake was designated 'A'. The letter designation continued outward and ended with the strake immediately inboard of the stringer plate, or on the Bridge (B), Shelter (C) and Saloon (D) Decks, the strake immediately inboard of the inner stringer. Like the shell plates, the individual plates within each strake were also numbered; however, in a departure from the system used with the shell plates, Harland & Wolff commenced the numbering of the deck plates from the after end of the ship and progressed forward. The sole exception to this was with the plates of the Tank Top; like the shell plates of the hull, these were numbered from the forward end aft. This was presumably done for the convenience of the shipwrights constructing the double bottom; since they would be dealing with the bottom shell plates and inner bottom plates at virtually the same time, numbering these plates in opposing directions would have inevitably led to some confusion among those assembling this complex structure.

Of necessity, numerous openings – engine and boiler casings, hatches, companionways, etc. – had to be cut

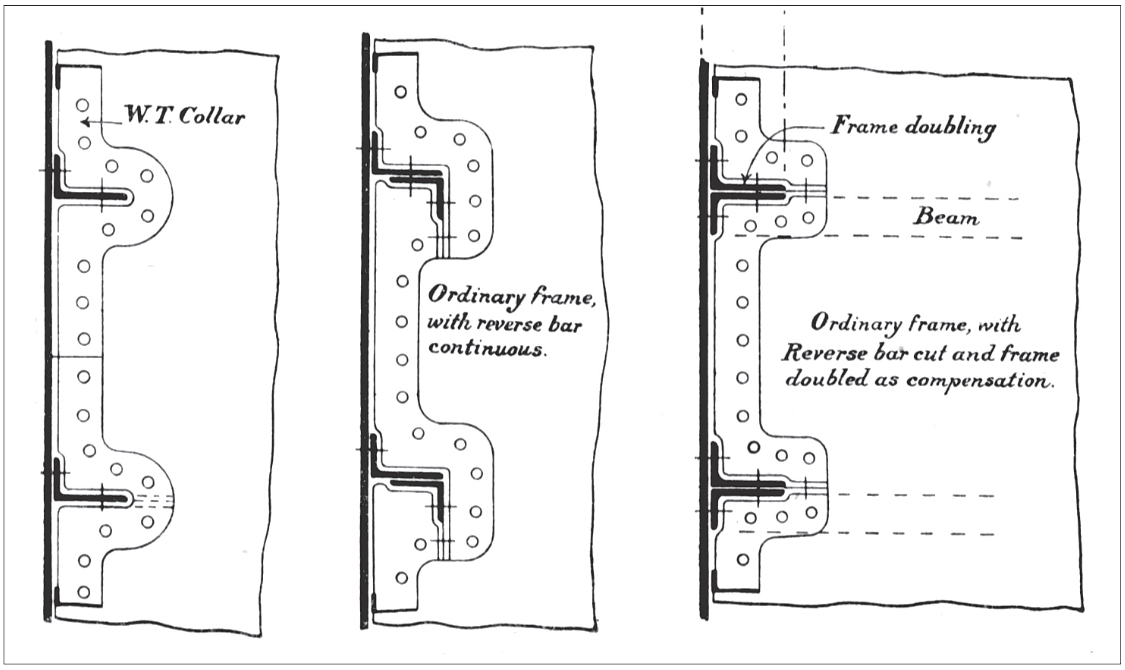

W.T. Collar
Ordinary frame, with reverse bar continuous.
Frame doubling
Beam
Ordinary frame, with Reverse bar cut and frame doubled as compensation.

Fig. 8-12 **Watertight Shoes** – Typical examples of various types of watertight 'shoes.' A 'shoe' was a watertight collar installed on a horizontal surface such as a deck or deck head to create a watertight seal around vertical structural members. These fittings created a seal around a steel frame or other vertical structural member where it passed through or connected to a plate, allowing for watertight caulking. Shoes were made in different types of steel, or from wrought iron depending on the strength required where they were fitted.

through the decks of any ship. This naturally reduced the strength of the deck, and compensation in some degree was provided both by thicker deck plating and by doublings in the way of these openings. The aim was to secure a compensation equaling at least 80 per cent of the maximum sectional area of the plating removed in creating the opening. Where possible, the butts of adjacent strakes were kept at least two frame spaces clear of each other; alternate strakes were kept at least one frame space clear of each other. The plating of the deck at the sides of hatches and engine and boiler openings was increased in thickness; doublings were fitted at the corners of the openings for all large hatchways and for engine and boiler casings as, otherwise, there was a tendency for the plates to rupture due to the severity of the racking stresses in these areas. Doublings were fitted to the decking under the windlasses on the Forecastle Deck, and intercostal girders were introduced underneath. The same applied for the anchor crane seating on the Shelter Deck (C) and the thick plating beneath the rudder steadiment aft. Cast-iron shoes were fitted between the frames at the connection of all sections constructed as 'watertight flats', except at the ends of the vessel where the shoes were wrought steel. Smithed shoes were fitted between the frames over the fresh-water tanks, on the watertight flat above the After Peak Tank, and also in way of the boss arm castings.

Water seepage beneath deck sheathing was a common occurrence despite every possible precaution being taken throughout the vessel to prevent it. Because of this, the steel decking was coated with a reliable bitumastic composition to protect against the havoc that could be caused by water finding its way through defective caulking in the seams and butts in the wooden sheathing laid over top of it.

In the case of upper decks uncovered by deckhouses and other parts of the superstructure, watertightness against the shell plating was secured by caulking the stringer bar against the plates of both the shell and the deck. In the 'tween decks, where the frames passed through the deck stringers, the space between shell and the stringer bar was filled with a good quality cement in areas where dampness was likely to be a concern. This was done to prevent water from pooling in this space and laying against the steelwork.

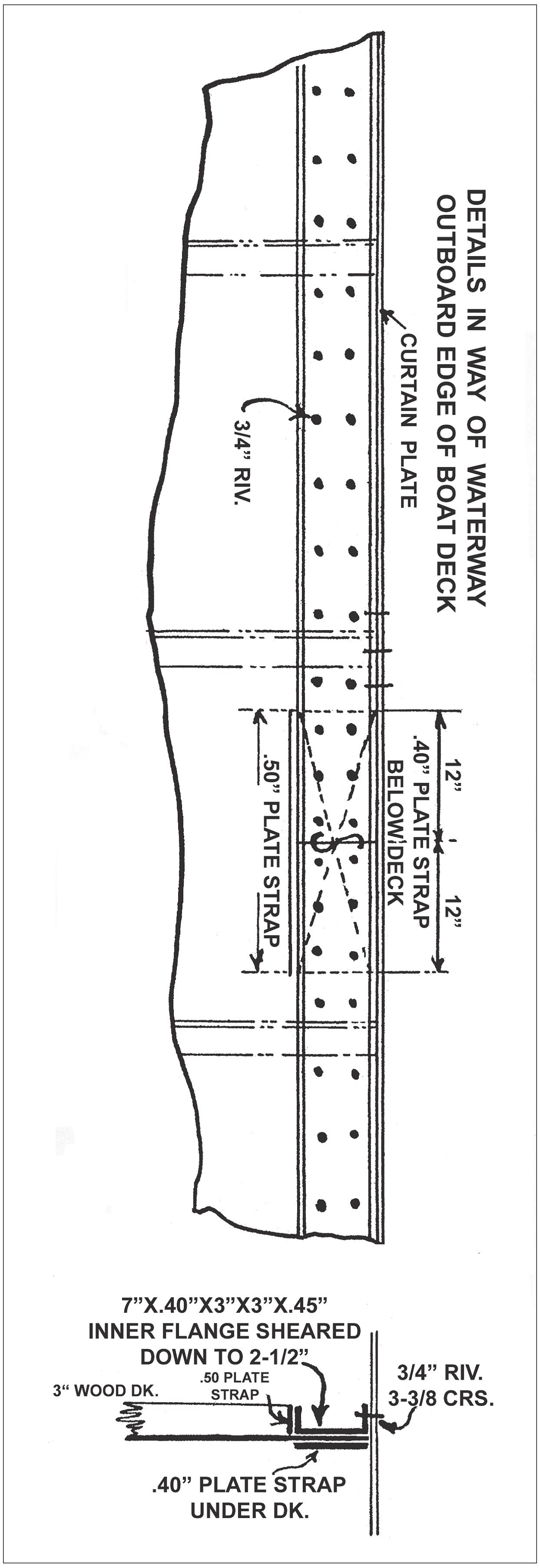


Fig. 8-13 **Structural Details of a Waterway** – This drawing shows the typical structural components which form the boundaries of the waterways. This example is from the Boat Deck. *(Illustration by Bruce Beveridge based on original H&W Boat Deck Iron drawing)*

Waterways and scuppers

To drain water from the weather decks, all were provided with waterways and scuppers. The waterways were fitted along the sides of the longitudinal bulwarks, sheer strakes and shell plating, and abutted against the margin planks of the wood sheathing over the steel decking. Some

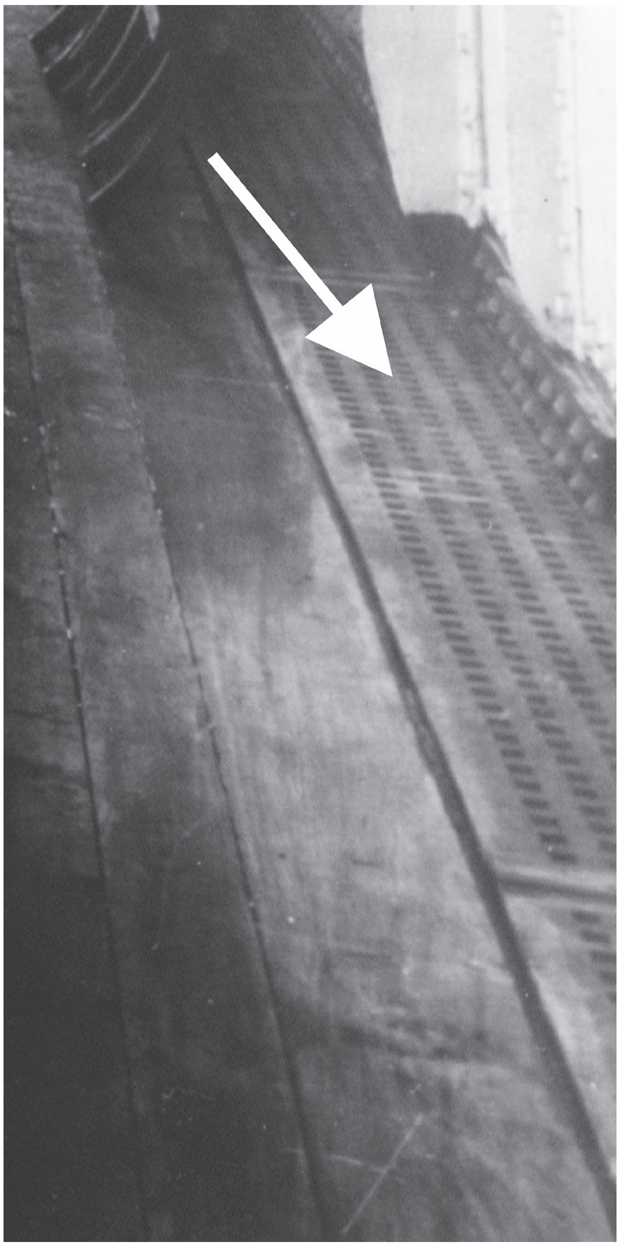


Fig. 8-14 **Limber Boards** – This detail, taken from a photograph of the Second Class B Deck Promenade on *Olympic*, shows teak limber boards (indicated by the arrow) placed over the waterway.

waterways, like those around the raised roofs on the Boat Deck, were made of channel section, but most were constructed of angle bar. In these instances, the stringer bar formed the outboard edge of the waterway, while a second angle which tightly abutted the deck margins formed the inboard edge; the deck stringer plate to which these were riveted formed the bottom. Visually, both channel and angle bar waterways had the appearance of water troughs or gutters. The vertical flange of angle bar or channel which abutted the wood deck was shaved down to match the finished height of the planks.

When fitted in the lower deck spaces where wood sheathing was not used, the edges of the waterway bars were adjusted to the height of the Litosilo[1] or other deck sheathing. Where the waterways were present in promenade spaces and were protected from the weather, they were covered with teak grates called 'limber boards'. The waterways within the well decks were of greater width than those found elsewhere on the ship, and were provided with wood batten covers which were put into place when necessary. None of the gratings were permanently mounted; this allowed for easy removal for cleaning and painting of the waterways, and also allowed those gratings in exposed areas to be quickly taken up and stowed in the approach of bad weather.

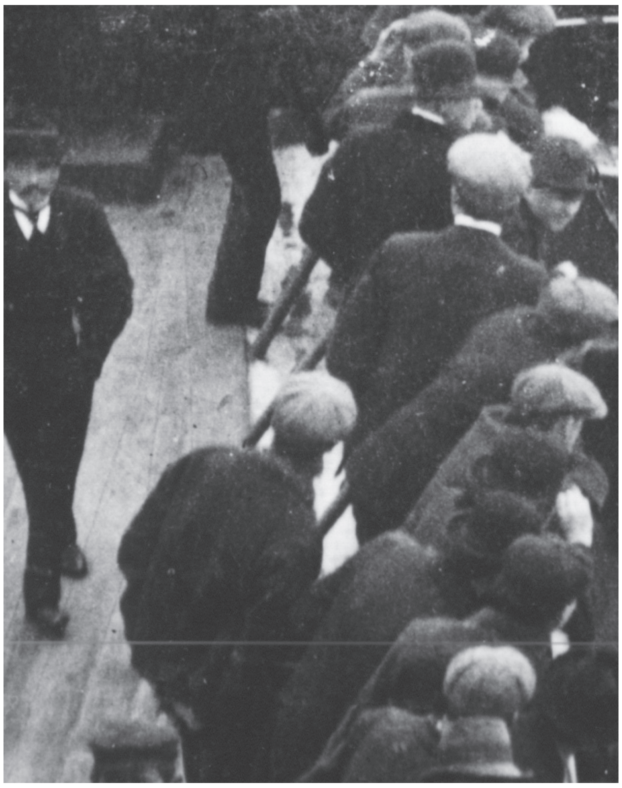


Fig. 8-15 **Limber Boards, Forward Well Deck** – In this detail from a photograph looking down onto the starboard side of *Titanic*'s forward Well Deck, limber boards are visible over the starboard side waterways. These appear to be painted white or are possibly fresh, uncoated wood. *(Father Browne photograph/ Authors' collection)*

Instead of waterways, the perimeter of the wood decking on the raised roofs was fitted with 6in-tall wash plates (sometimes called 'wash boards' or 'toe plates') which formed a coaming around the roofs. These were also fitted on the house tops where wood decking was fitted. These plates were in place to keep rain and wash-deck water from spilling over onto the deck below.

All of the waterways and gutterways were provided with drain holes and pipes called 'scuppers'. To prevent dirty water from trickling down over the cabin windows, scupper pipes were led down and passed through the vessel's side below. Special scuppers were fitted along the sides of the superstructure to discharge the water from the expansion joints. Additionally, the forward ends of *Titanic*'s A and B Deck promenades were fitted with rectangular wash ports, one on each side at the respective deck levels, in order to quickly drain the large amounts of water with which could, and often did, inundate these areas when driving ahead through high seas.

Collectively, there were a large number of scupper, water closet, and lavatory drainage pipes. To keep the number of these openings through the shell plating to minimum, groups of these were conjoined to form single larger pipes of 5 or 6in in diameter, made of galvanized iron. These were led down to discharge openings in the shell plating just above the waterline. Storm valves were installed at the outlet of each discharge to keep sea water from passing back up through the pipes.

Where water could collect on a lower deck from being washed down with a hose, through condensation, or through leakage from the deck openings overhead, waterways and scupper pipes were provided. The scupper pipes in *Titanic* provided in conjunction with the 'tween deck accommodations were fitted with siphon traps so that the smell from dirty bilge water did not pass upward and pervade the interior crew and passenger spaces. Another source of drainage on the lower decks were the sidelights; they tended to condense water, sometimes they leaked, and when open, they could admit water or spray. To collect this water, drip pans were fitted below the sills of the lights; in some cases, in lieu of fitting a drip pan a small vertical scupper pipe was led from the sill of each light down to a larger fore-and-aft pipe, which discharged into a lower deck scupper. These pipes were covered by joinery in the better cabins.

Certain steam-powered deck auxiliaries required provision for drainage as well. For example, the sole plates beneath the steam winches on the Forecastle Deck were fitted with scupper pipes to collect and drain away dirty and oily water resulting from the leakage of steam past the glands and seals, which was routine with this type of apparatus.

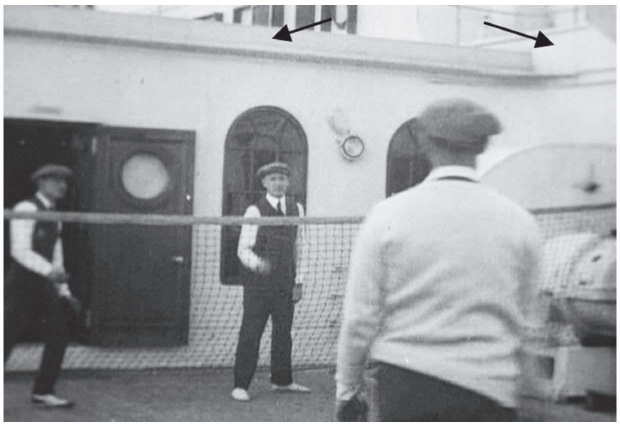


Fig. 8-16 **Wash Plates** – This image, filmed aboard *Olympic* in the early 1920s, shows the wash plates (indicated by arrows) above the First Class Entrance. The one to the right extended aft longitudinally over the casing for a short distance and forward to the port side corner of the staircase dome cover. The plate to the left extended partially around the roof over the Entrance hall. Wash plates were fitted to prevent rainwater from splashing onto the decks below, directing it instead towards scuppers located along the deckhouse roofs. *(From an original White Star Line promotional film/Authors' collection)*

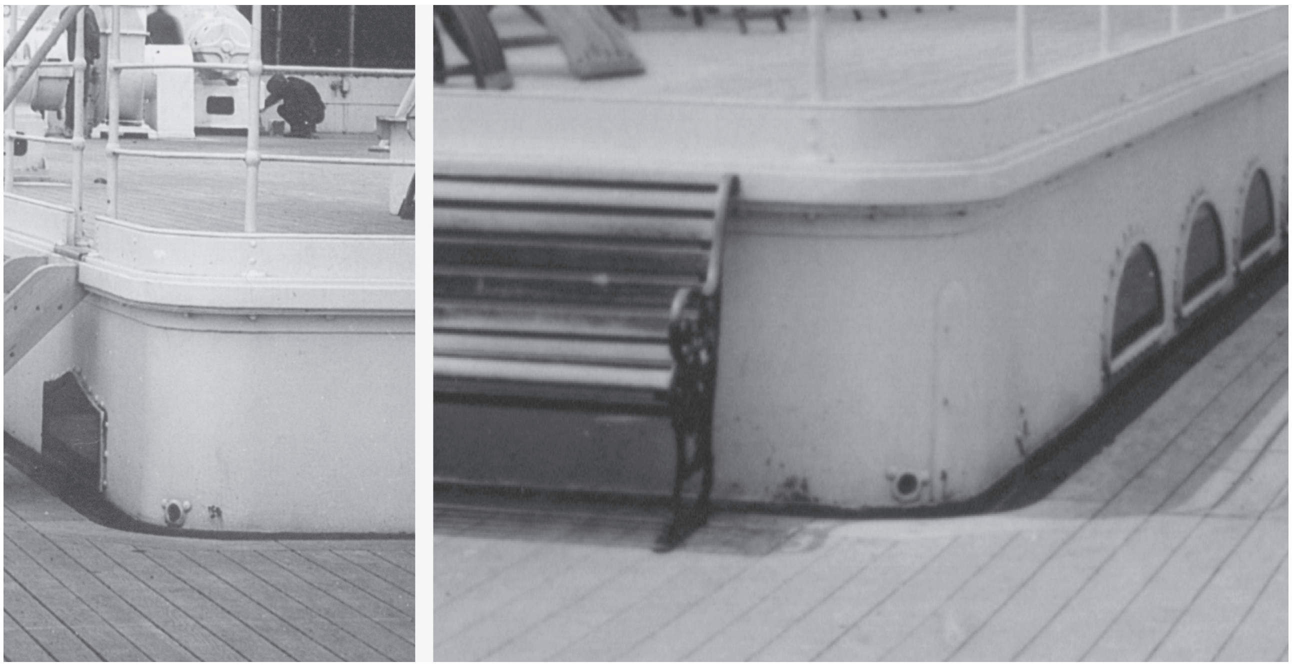


Fig. 8-17 **Scuppers and Waterways In Way of Raised Roofs on *Olympic*** – At left, the after port corner of the raised roof over the First Class Lounge; at right, the starboard after corner of the raised roof over the First Class Smoke Room. In both images, a small drain hole is visible at the base of the plating; this was a drain scupper for the water which collected on the raised roof deck immediately above. *(Right image authors' collection; left image Peter Davies-Garner collection)*

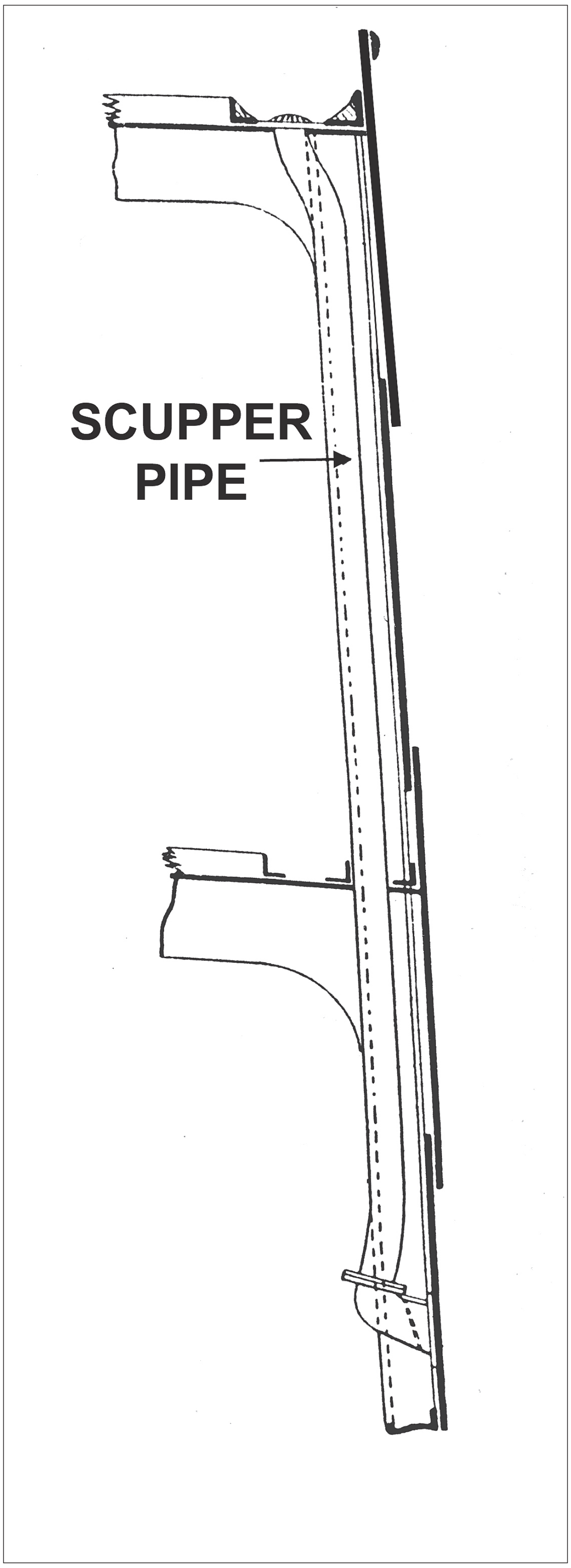


Fig. 8-18 **Scupper Pipes** – This illustration shows the manner in which scupper pipes were carried through multiple decks to discharge openings along the ship's side.

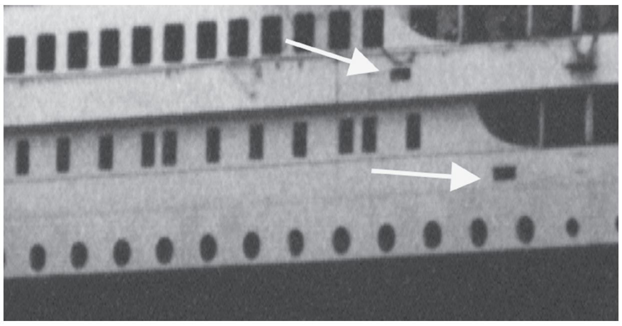


Fig. 8-19 **Wash Ports** – The two rectangular wash ports at the forward ends of A and B Decks. Surprisingly, *Olympic* did not originally have these two wash ports. Only one of these would be fitted later in her career – the lower one – and in a smaller size.

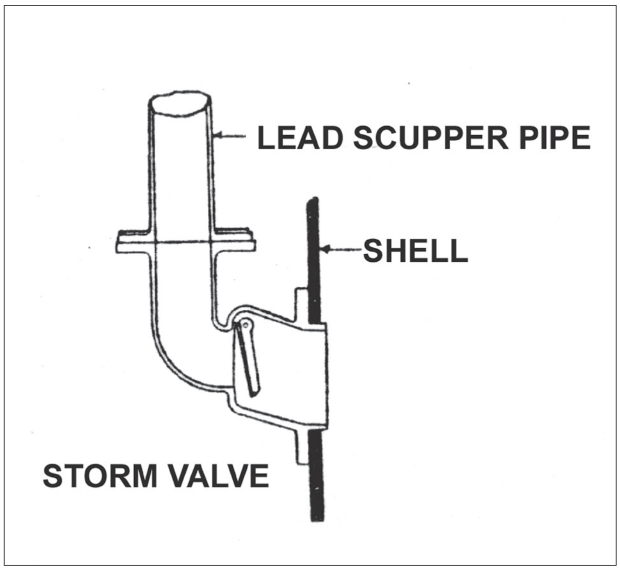


Fig. 8-20 **Storm Valve** – This illustration shows a storm valve typical of those fitted in the shell plating at the discharge openings of scupper and soil pipes to prevent sea water from passing back up through the pipes.

Wooden deck planking

The specifications for wood planking were very strict and only the best materials were considered satisfactory for this use. With only a few exceptions, the Board of Trade regulations required all of the weather decks to be completely plated. Above all living spaces, the weather decks were sheathed with wooden planks laid over the steel deck plating. Wood planking helped to insulate the space below from the heat of the sun and kept the open decks from becoming too hot to walk on. Because the thick, non-conducting layer formed by the planking did not readily transmit heat or cold, air within the ship remained at a more even temperature, which lessened the tendency to alternately vaporize and condense so much moisture.

In passenger vessels, therefore, it was essential that the upper decks be sheathed in wood to prevent condensation

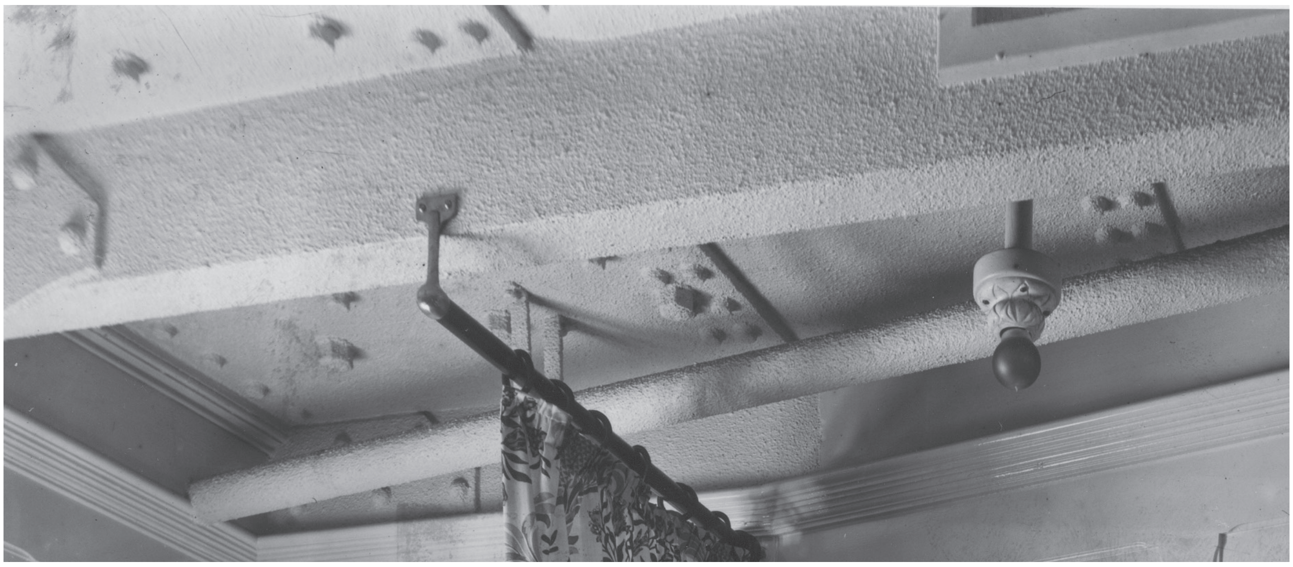


Fig. 8-21 **Granulated Cork Insulation** – This image of the overhead within an ordinary stateroom on *Olympic* shows the granulated cork applied as insulation. The cork was applied to the paint when it was wet. *(Daniel Klistorner collection)*

from above dropping onto the furniture, sleeping berths, etc. in staterooms placed immediately below a plated upper deck. It was also common to coat the plating forming the roof of the cabin with granulated cork. A coat of sticky varnish was applied, the granulated cork was dusted thickly over it, and then the whole was painted with two or three coats of white paint. This covering was such a good insulator that even if the deck above became cold; it would not immediately chill the contiguous air of the cabin. Granulated-cork coverings were also applied to pipes crossing along the overhead in a compartment or room in order to absorb condensation.

Titanic used two types of pine for her deck planking. Yellow pine was used throughout except in areas that would undergo excessive wear; these latter surfaces were laid with pitch pine.[2] Pitch pine is distinguished from yellow pine by its peculiarly rough, dark bark, and by its abundance of resin.

The planking was laid running longitudinally and was secured to the steel deck by galvanized iron bolts and nuts. With the deck planks tightly held down from above, the bolt holes were drilled from below, the previously punched holes in the steel deck plates guiding the drill. After the holes had been drilled through, they were counterbored from the topside of the decking in order to provide recesses for the bolt heads and deck plugs. The counterboring was done to specified depth regulated by a gauge. An improvised gauge usually consisted of

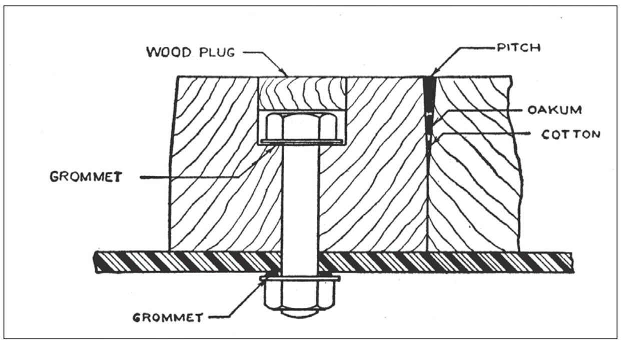


Fig. 8-22 **Section Through a Steel Deck Sheathed With Wood.** – This section shows the means of attaching the wood sheathing to the steel deck plating, and also shows the wood plug used to conceal the bolt head.

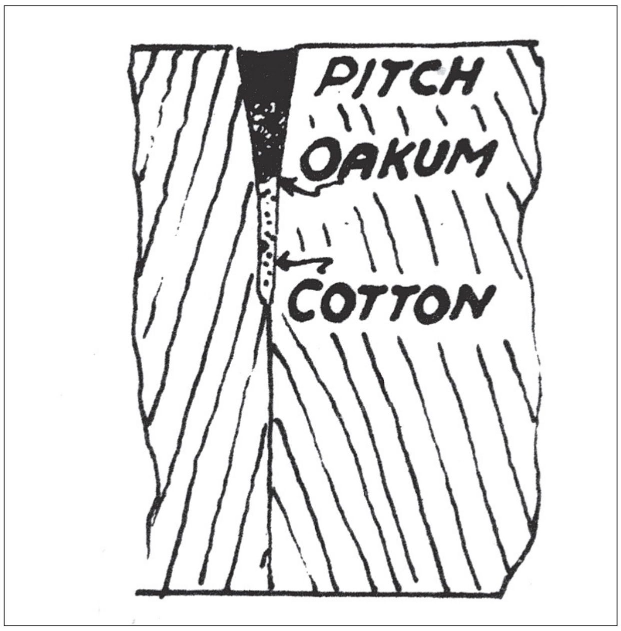


Fig. 8-23 **Section Through a Caulked Plank Seam**.

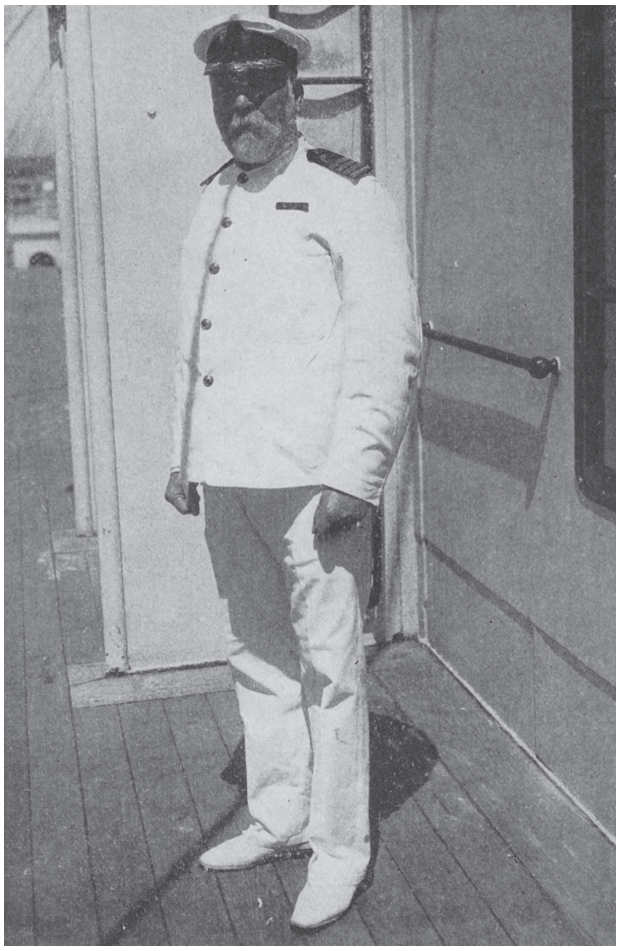


Fig. 8-24 **Boat Deck Detail on *Olympic*, 1911** – In this image of Captain Smith, taken just forward of the starboard First Class Entrance, the teak margin planks against the deckhouse are easily distinguished from the yellow pine planks of the decking. The visual difference is due to the greater width and the darker color of the teak planks.

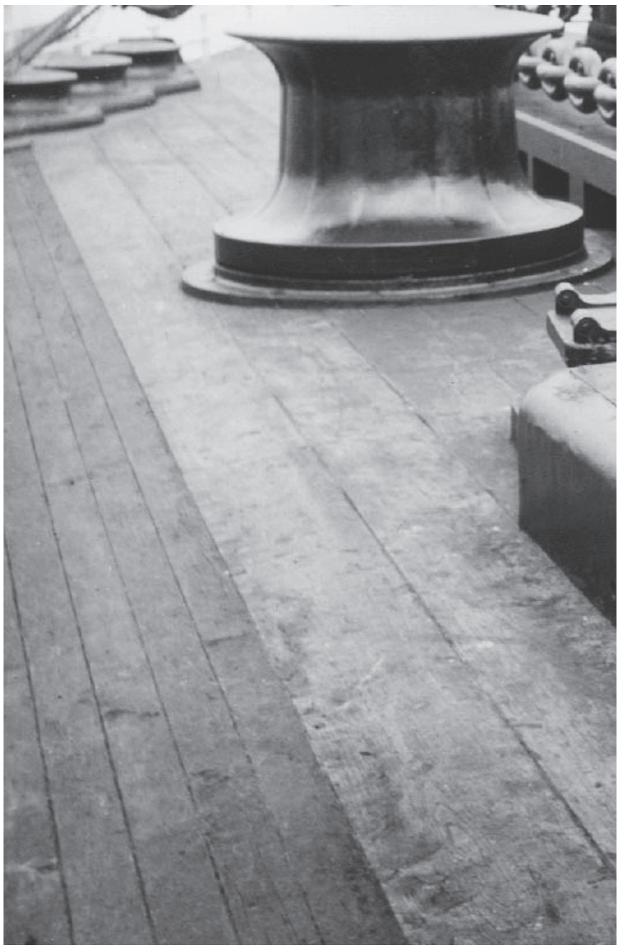


Fig. 8-25 **Plank Thickness Transitions** – In cases where two thicknesses of planking abutted, such as on the Forecastle Deck where pine met teak beneath the anchor and windlass equipment, the edges of the adjoining planks were planed to form a smooth transition, as shown in this photo of the 1899 *Oceanic*. *(H&W/Authors' collection)*

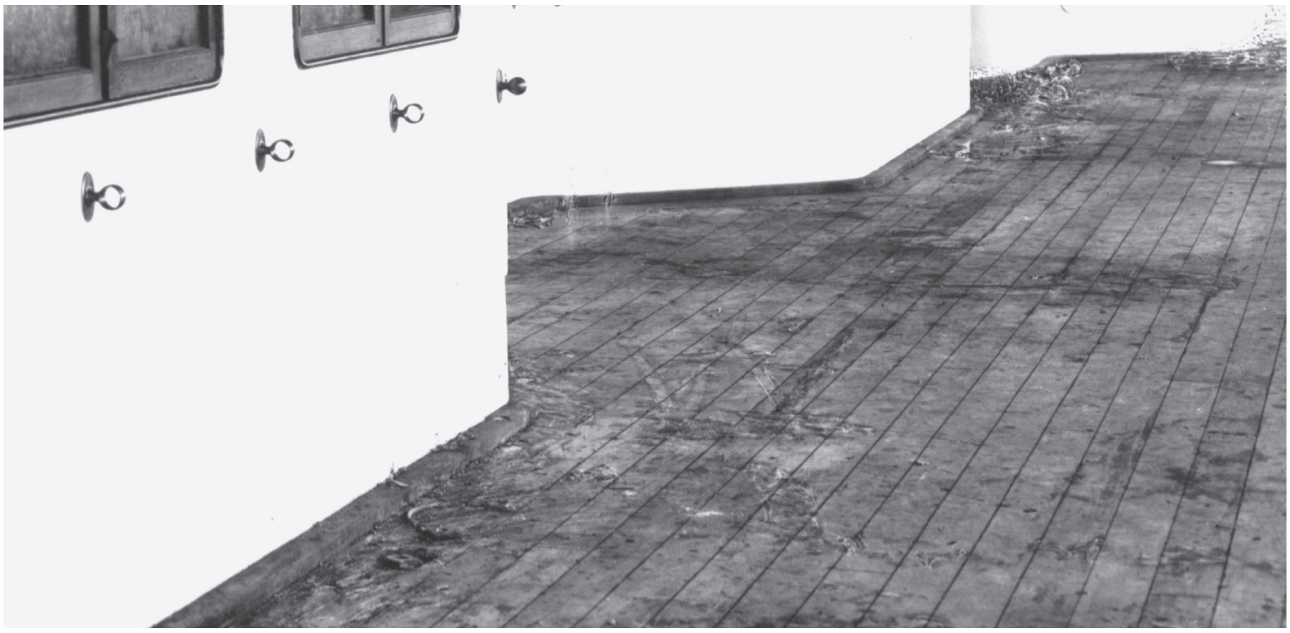


Fig. 8-26 **Deck With Shavings** – A section of recently planed decking on *Olympic*'s A Deck, with wood shavings still visible. *(H&W/Authors' collection)*

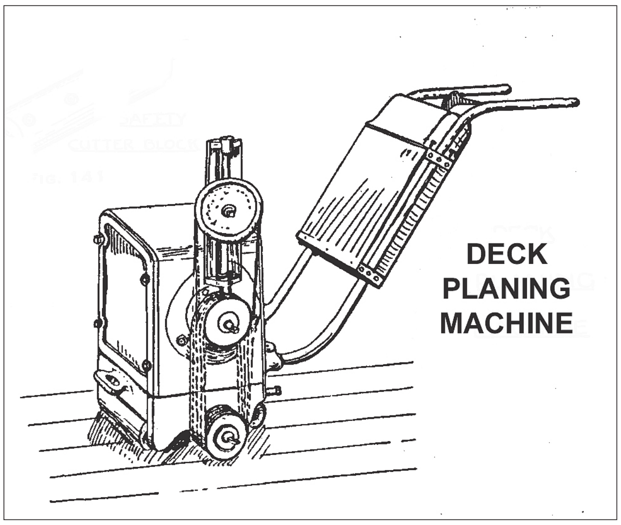


Fig. 8-27 **Planing Machine** – A typical electric deck-planing machine. Not many years before the building of *Titanic*, wood decks were planed by hand, by wood shipwrights working on their hands and knees. With this invention of this electrically powered tool, the job was made easier and considerably faster, with only the tight spots having to be done by hand.

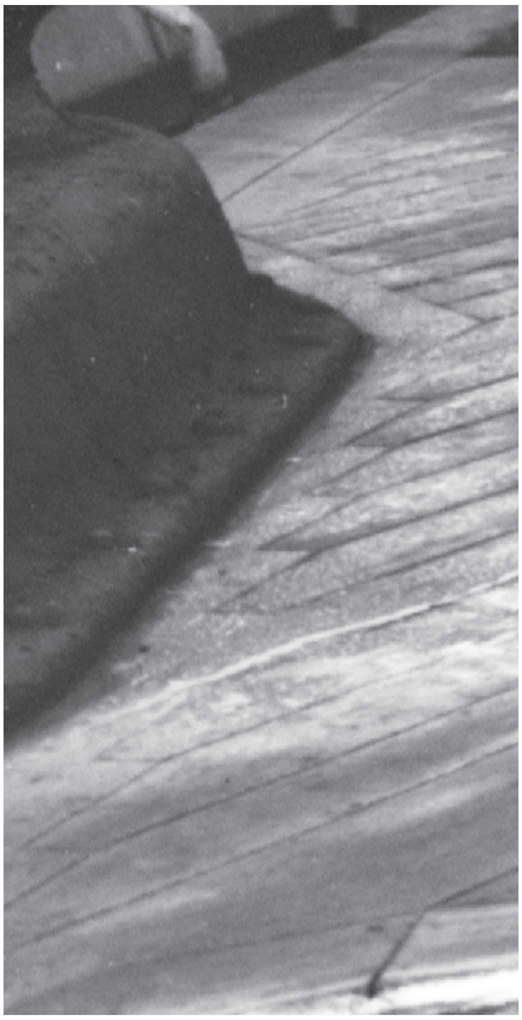


Fig. 8-28 **Nibbing on Forecastle** – Nibbed deck planks, shown here meeting the margin planks around the base of a roller fairlead on *Olympic*'s Forecastle Deck. *(H&W/Authors' collection)*

a simple square of hardwood, drilled and set at the desired distance from the point on the bit. The bolts were driven from above until they were hard down and far enough through to allow a nut to be secured from below. Sometimes the bolts were driven from beneath; in such cases, a slotted nut, turned by a large T-handle screwdriver, was covered by the deck plug. When driven from above, the deck bolts were installed with a small grommet under their heads, the grommet being made of lamp wick soaked in white lead to prevent leakage through the deck. When the bolts were driven from below, the nut had a similar grommet. In both instances, after the nuts were driven up tight, wooden plugs were dipped in white lead and driven into the counterbores. The plugs, made of the same material as the surrounding planks, were inserted with their grain oriented in the same direction as that of the decking.

The edges of the individual planks were given a slight bevel, after which the space between them was filled with oakum and cotton and then covered or 'payed' with marine glue or pitch. The small space which was left between the ends of the planks was similarly caulked and payed. All of this was to prevent moisture from getting underneath the deck planks where it would cause rot within planks and corrosion of the steel deck plates beneath them. It also prevented moisture from attacking and rotting the wood at the ends of the individual planks.

The decking was separated from the sides of the ship, or bulwarks, by the waterways. A wide plank known as a 'sheer plank' or 'margin plank' formed the outer boundaries of the decking. Other wide planks were fitted around hatches and scuttles, at the transverse boundaries of decks, next to waterways, around deckhouses and around foundations for winches, windlasses, ventilators and other machinery. Though at one time these various planks each had their own nomenclature, by the early twentieth century they had long-since become known collectively as margin planks. The margin planks on the exposed decks of *Titanic* were all made of teak because of the ability of this wood to resist rot from the constant moisture present in the seams where wood and steel or iron abut.

The style of planking used on *Titanic* was one of deck planking in strakes. This form of planking was arranged longitudinally, parallel to the centerline of the ship. On the Forecastle Deck where the deck narrowed at the sides of the ship, the ends of the planks were 'nibbed' or 'stepped' into the inner edge of the wide margin plank, the latter having a series of corresponding notches.

Nibbing was used to avoid pointed or 'feathered' edges. Because the latter were nearly impossible to caulk, the tapered plank was always cut off and nibbed. This also

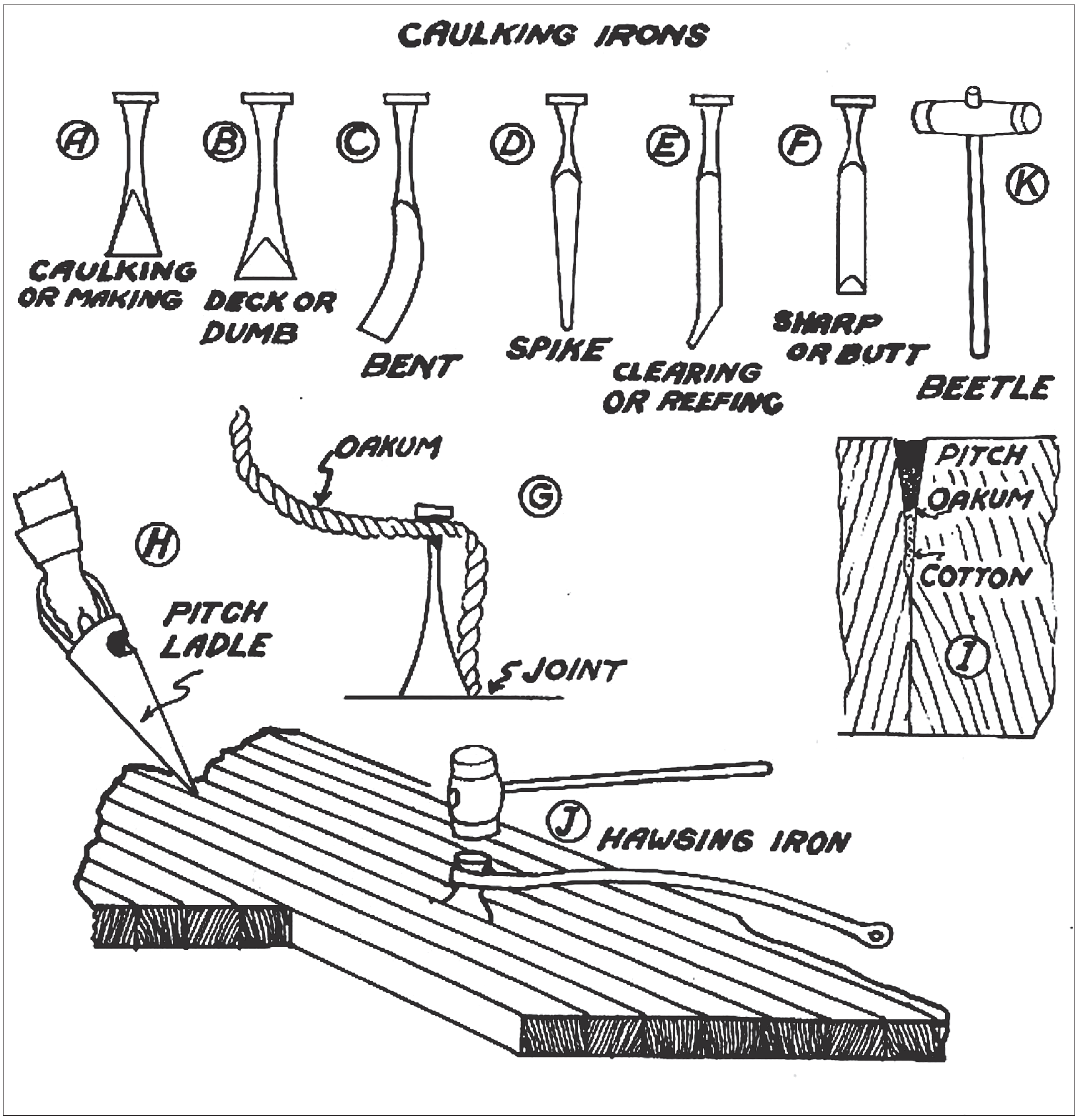

CAULKING IRONS
A
CAULKING OR MAKING
B
DECK OR DUMB
C
BENT
D
SPIKE
E
CLEARING OR REEFING
F
SHARP OR BUTT
K
BEETLE
OAKUM
G
JOINT
H
PITCH LADLE
PITCH
OAKUM
COTTON
I
J
HAWSING IRON

Fig. 8-29 **Tools Used for Deck Caulking**.

permitted edge nailing, when required, which would have been impractical with a thin-feathered edge.

The planking was cleaned and smoothed on both sides before installation, and the final work was planed, evidence of which can be seen in photographs of the *Olympic* while fitting-out at Harland & Wolff.

Deck caulking tools and methods are shown in Fig. 22.

The caulking or 'making' tool A was used to drive the oakum into the joint or seam after it had been opened by the deck- or dumb-iron, B. The bent tool C was also used for opening joints while the narrow 'spike' D was used in caulking small joints. Joints were cleaned out by the clearing or 'reefing' tool E, and the 'butt' tool F was used as a chisel in enlarging a butt joint to proper width and depth. The peculiar long-headed wooden maul used in striking these irons was called a 'beetle', K.

In large-scale caulking such as that used on *Titanic*, the seams were first opened up with the reaming iron, and after being properly cleaned and opened to sufficient depth, were partially filled with cotton spun yarn. A layer of oakum was then driven on top of the cotton, as at G. Further driving was carried out by two men, one swinging a maul and the other holding the 'hawsing' iron J. Finally, the caulked seams were payed with pitch,

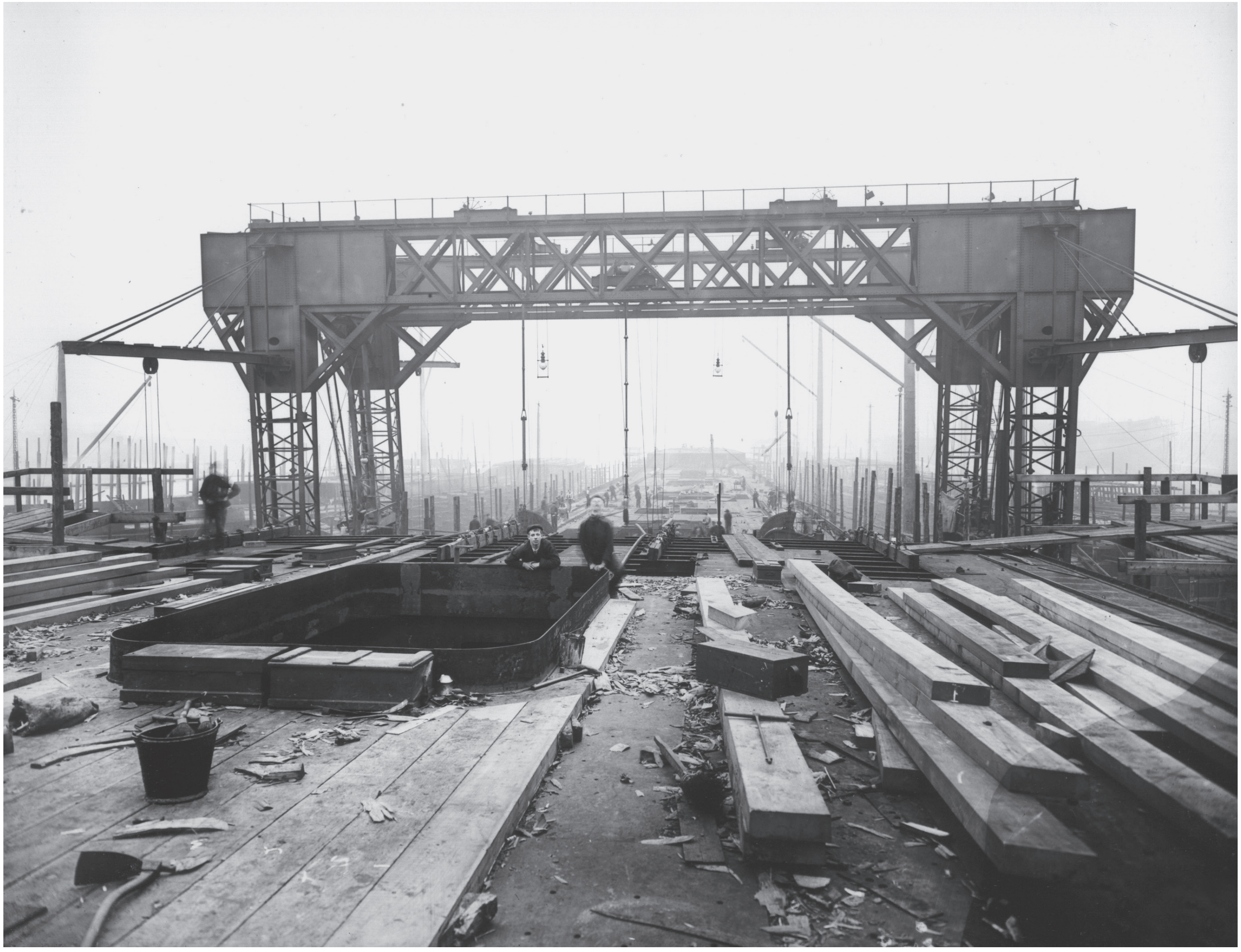


Fig. 8-30 **Laying Wood Decking** – In this September 1898 photograph, shipyard workers lay wood decking aboard the *Oceanic*. The tools of their trade can be seen lying around the deck among the stacks of planks awaiting installation. *(H&W/Authors' collection)*

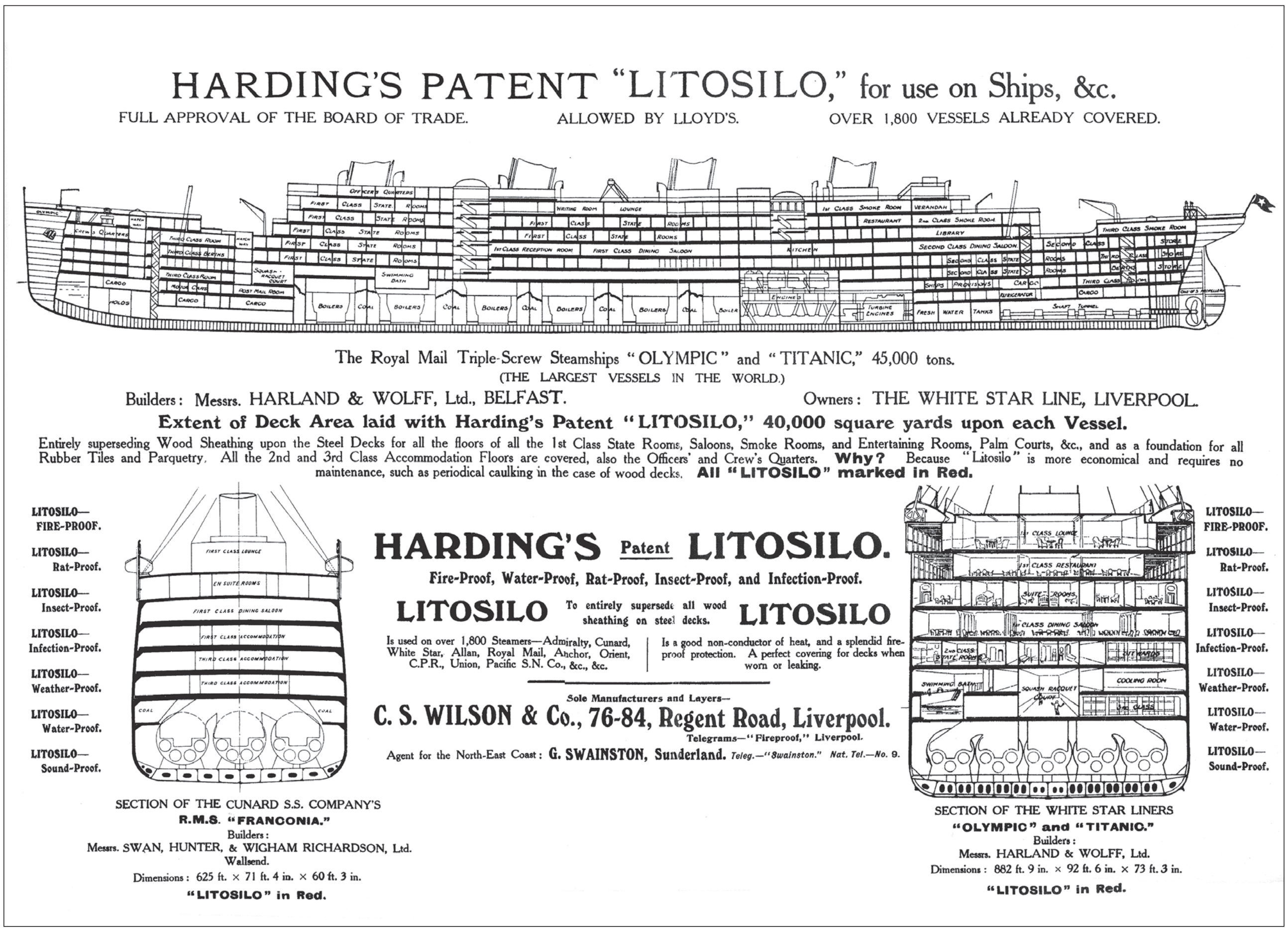
poured from a special type of ladle H, a cross-section of the finished job resembling that at I. One thread of woven cotton, followed by two threads of oakum, was sufficient for new decks aboard most commercial vessels.

Interior deck sheathing

The decks of the ship not exposed to weather were covered in a number of ways. Wood planking was laid down around and beneath the steering gear and the warping and cable-handling machinery. The decks of certain 'working' areas within the ship were also sheathed in wood; one such example was the working crew passageway along E Deck, which was exposed to both constant foot traffic and the movement of heavy weights along the deck surface. Wood deck sheathing, where fitted inside the ship, was laid and finished in much the same manner as when laid on the weather decks. One exception to this were the wooden planks laid down in the refrigerated spaces, which were laid loosely over top of wood battens laid perpendicular to the planks; raising the planks in this manner permitted the chilled air within the compartment to circulate beneath crated stores laid on the planks, while preventing stores or cargo laid on the deck from coming into contact with any spillage or thawed liquids which might collect. The loose decking also permitted the latter to be easily accessed and cleaned up.

Within interior spaces that were exposed to constant moisture or heat, the decks were most often covered in ceramic or brick tile. Areas of the ship which received such deck coverings were water closets, lavatories, bathrooms, and pantries in both the passenger and crew accommodations, as well as the galleys and their ancillary spaces. The decks within the Swimming Bath compartment and much of the Turkish Bath suite were also laid in ceramic tiles. The decks of many of the passenger staterooms and public rooms, as well as those of some parts the crew's quarters were laid with a type of linoleum tile that was generically referred to as 'lino' tiles. Additionally, in the passenger accommodation, carpet and parquetry could also be found.

While wood planking could be laid directly onto the coated steelwork of the decks, deck materials such as



HARDING'S PATENT "LITOSILO," for use on Ships, &c.

FULL APPROVAL OF THE BOARD OF TRADE. ALLOWED BY LLOYD'S. OVER 1,800 VESSELS ALREADY COVERED.

The Royal Mail Triple-Screw Steamships "OLYMPIC" and "TITANIC," 45,000 tons.
(THE LARGEST VESSELS IN THE WORLD.)

Builders: Messrs. HARLAND & WOLFF, Ltd., BELFAST. Owners: THE WHITE STAR LINE, LIVERPOOL.

Extent of Deck Area laid with Harding's Patent "LITOSILO," 40,000 square yards upon each Vessel.

Entirely superseding Wood Sheathing upon the Steel Decks for all the floors of all the 1st Class State Rooms, Saloons, Smoke Rooms, and Entertaining Rooms, Palm Courts, &c., and as a foundation for all Rubber Tiles and Parquetry. All the 2nd and 3rd Class Accommodation Floors are covered, also the Officers' and Crew's Quarters. **Why?** Because "Litosilo" is more economical and requires no maintenance, such as periodical caulking in the case of wood decks. **All "LITOSILO" marked in Red.**

LITOSILO—
FIRE-PROOF.
LITOSILO—
Rat-Proof.
LITOSILO—
Insect-Proof.
LITOSILO—
Infection-Proof.
LITOSILO—
Weather-Proof.
LITOSILO—
Water-Proof.
LITOSILO—
Sound-Proof.

HARDING'S Patent LITOSILO.

Fire-Proof, Water-Proof, Rat-Proof, Insect-Proof, and Infection-Proof.

LITOSILO To entirely supersede all wood sheathing on steel decks. **LITOSILO**

Is used on over 1,800 Steamers—Admiralty, Cunard, White Star, Allan, Royal Mail, Anchor, Orient, C.P.R., Union, Pacific S.N. Co., &c., &c.

Is a good non-conductor of heat, and a splendid fire-proof protection. A perfect covering for decks when worn or leaking.

Sole Manufacturers and Layers—
C. S. WILSON & Co., 76-84, Regent Road, Liverpool.
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Agent for the North-East Coast: **G. SWAINSTON, Sunderland.** *Teleg.—"Swainston." Nat. Tel.—No. 9.*

SECTION OF THE CUNARD S.S. COMPANY'S
R.M.S. "FRANCONIA."
Builders:
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Wallsend.
Dimensions: 625 ft. × 71 ft. 4 in. × 60 ft. 3 in.
"LITOSILO" in Red.

SECTION OF THE WHITE STAR LINERS
"OLYMPIC" and "TITANIC."
Builders:
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Dimensions: 882 ft. 9 in. × 92 ft. 6 in. × 73 ft. 3 in.
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FIRST CLASS LOUNGE
EN SUITE ROOMS
FIRST CLASS DINING SALOON
FIRST CLASS ACCOMMODATION
THIRD CLASS ACCOMMODATION
THIRD CLASS ACCOMMODATION
COAL
COAL
1st CLASS LOUNGE
1st CLASS RESTAURANT
SUITE ROOMS
1st CLASS DINING SALOON
2ND CLASS STATE ROOMS
STEWARDS
SWIMMING BATH
SQUASH RACQUET COURT
COOLING ROOM
3RD CLASS
FIRST CLASS STATE ROOMS
1st CLASS RECEPTION ROOM
FIRST CLASS DINING SALOON
KITCHEN
SECOND CLASS DINING SALOON
LIBRARY
THIRD CLASS SMOKE ROOM
THIRD CLASS ROOM
THIRD CLASS BERTHS
MOTOR CARS
POST MAIL ROOM
SQUASH-RACQUET COURT
SWIMMING BATH
CARGO
HOLDS
BOILERS
COAL
ENGINES
TURBINE ENGINES
FRESH WATER TANKS
SHIPS PROVISIONS
REFRIGERATOR
SHAFT TUNNEL

Fig. 8-31 **Litosilo Advertisement**. *(*The Shipbuilder*/Authors' collection)*

those just enumerated required some form of substrate material to be laid beneath them. This substrate layer served in some cases to protect the steelwork below from the effects of moisture, while in other cases, it served to insulate the spaces it was laid in from noise and heat which might be transmitted through the deck; in all cases, this sub-layer also provided a fair, even surface on which to lay the 'finished' deck coverings and partition joinery.

Beneath ceramic and brick tiles, a layer of Portland cement was laid down over the steel deck; the thickness of this layer of cement could be up to 2in depending on the thickness of the plate seams beneath. The tiles were then bedded in a thin mortar troweled over the cement, after which the seams were grouted. Beneath other types of deck coverings, where constant wetting or high heat was not a consideration, magnesite compositions of one type or another were generally adopted. Such materials were as easily mixed and applied as Portland cement, but were only half as heavy, and were also better at insulating against the transference of noise and heat. In the case of *Titanic*, the composition chosen was Harding's patent Litosilo, supplied by C.S. Wilson & Co. of Liverpool.

Litosilo was a continuous plastic mass which made a solid, resilient deck. Litosilo had an elastic quality that gave with the expansion and contraction of the steel deck plates; in the dry locations where it was applied, it proved to be more durable than concrete because of its tendency, under normal conditions, not to crack, crumble or disintegrate. As a further bonus, the composition was noncombustible. Because of these qualities and because of the ease with which it could be applied, Litosilo was viewed as an ideal material whether applied as the actual finished deck surface or as the substrate layer beneath 'lino' tile or carpet.

Typically, the coloring of Litosilo was a pinkish red. It could, however, be furnished in any color specified. Most often, the color was of little importance because the composition was usually hidden beneath the final floor covering. In the First Class staterooms, for instance, the Litosilo was most often covered by carpeting, while in most of the public rooms and corridors, 'lino' tiles laid in a variety of decorative patterns and colors covered the composition. Throughout Second Class, 'lino' tiles again covered the floors of Litosilo-laid public rooms, as well as the floors of staterooms and corridors. In the Third Class areas, while the Litosilo sheathing of

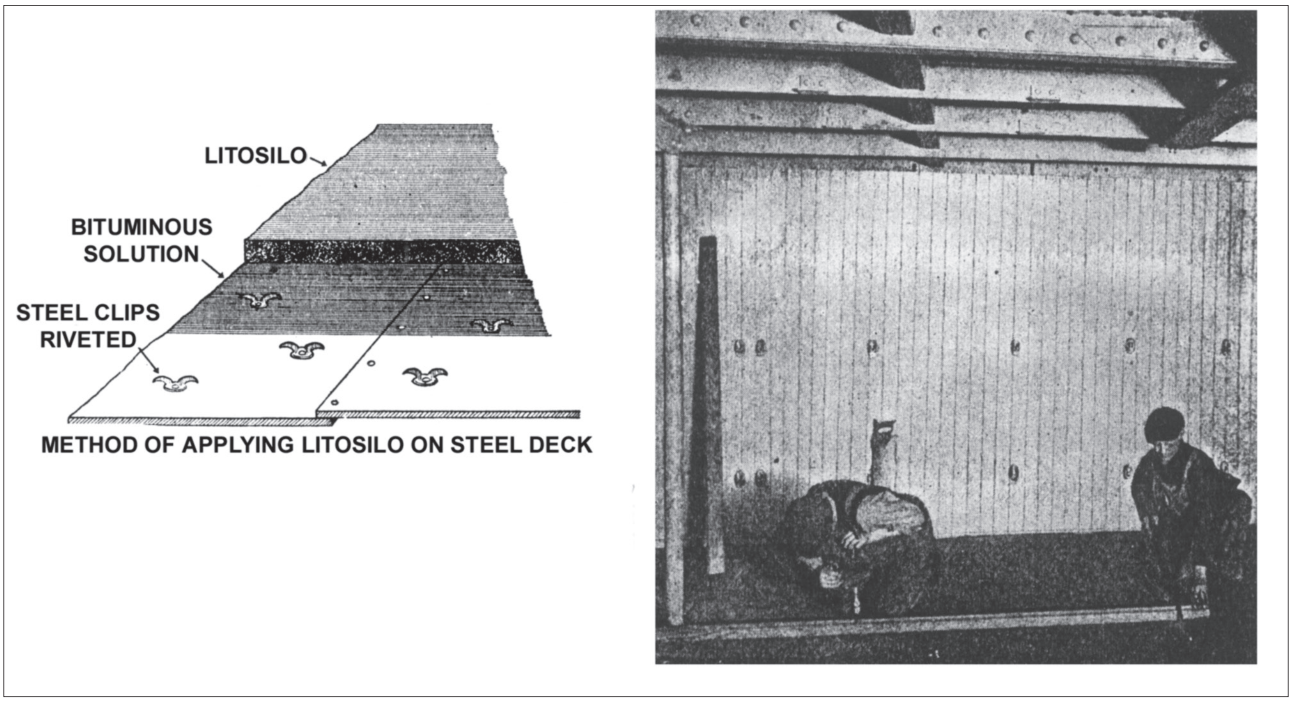


Fig. 8-32 **Method of Applying Litosilo** – At left, an illustration showing the basic steps involved in applying Litosilo to the underlying steel deck. At right, an image from an advertisement shows men attaching a wooden bulkhead sill, or 'cant,' to the hardened Litosilo.

passengers' cabins, the General Room and the Smoke Room was laid with 'lino' tiles, the deck within in the Dining Saloon was laid in bare, colored Litosilo alone. Throughout the quarters of the crew, the decks were sheathed primarily with colored Litosilo with no other floor coverings laid on top.

One notable exception to the use of Litosilo on the decks throughout the passenger accommodations was found in the after Second Class staterooms on F and G Decks, the after Third Class rooms on G Deck that were directly above the refrigerated spaces, and above the after Shaft Tunnels. Rather than Litosilo, the sheathing beneath the 'lino' tiles in these spaces was made of wood. The wood sheathing served a double purpose here: first, it was a better insulating material for refrigerated spaces below and, secondly, the wood was far less affected by any condensation which might form on the steel deck surfaces over these areas.

Litosilo was laid with a trowel while in a soft pasty state. It was applied about 2in-thick, drying in ten hours in summer, to about forty-eight hours in mid-winter. Evidence from *Titanic*'s wreck illustrates that the Litosilo was laid in two coats. The bottom layer was gray in color, and is most probably the composition in its raw and least expensive state; the top coat was laid in the aforementioned pinkish red color. While a possible saving in material cost may have been realized from the application of an uncolored first layer, a real saving in time was certainly achieved; laying the composition in two thinner layers rather than one heavy one was found to result in an overall quicker drying time. Once set, this flooring material was stable enough for the joiners to screw the bottom sills, or 'cants', of bulkheads directly to the composition.

Litosilo had some serious disadvantages, of which all shipbuilders were aware. It was apt to expand while settling, consequently having an adhesive force that was poor, at best; it also tended to leave the deck and rise up in places when this happened, whereupon it soon cracked and allowed water to seep below. For this reason, use of Litosilo was avoided in areas that were frequently exposed to considerable wetness, such as bath and galley floors. When laid on a plated deck, boundary bars had to be riveted to the plating to aid adhesion. The areas where Litosilo was laid were fitted with shallow cleats or mushroom-like studs to assist in holding it down. However, because of the composition's ability to expand and contract with changing temperatures, and from stress brought upon the deck from the working of the ship, it was still known to crack around the cleats.

A more serious disadvantage with Litosilo was brought to the attention of shipbuilders and surveyors not long after this material had been used aboard *Olympic* and *Titanic*. By this time it was already known that this material was unsuitable for use as either a deck covering, or as a substrate beneath other deck coverings, in areas which frequently became wet. What was not realized up until this point was that, in the presence of water, this material slowly decomposed; as this occurred, the magnesium chloride in the composition dissolved and leached out, coating the deck plates beneath with a chemical that was actively corrosive to iron and steel. The problem was first discovered in ships which, by 1912, had been in service for a decade or more. It was found that where leakage had occurred – for instance, from the caulking of deckhouse boundary bars loosening over time from the working of the ship – the nearby Litosilo had absorbed the water. As a result, the magnesium chloride was washed out, causing the deck plates beneath to corrode through in large holes, necessitating expensive repairs. As a result, with ships built immediately following this period, a switch was made to other compositions such as 'Veitchi', which did not contain magnesium chloride.

General Specifications of Deck Sheathing and Waterways

Boat Deck:

Channel waterway at sides of deck: 7in x .40in x 3in x 3in x .45in, inside flange sheared down to 2½in.

Channel waterway around raised roof over First Class Smoke Room, First Class Lounge and Reading and Writing Room: 7in x .40in x 3in x 3in x .45in, inside flange sheared down to 2½in.

Where exposed to the weather, deck sheathed in 5in x 3in yellow pine; raised roofs and wood-sheathed house tops sheathed in 5in x 2½in yellow pine. Teak margin planks bordering all deckhouses, waterways, machinery footings, deck margins, and expansion joints – beveled around deckhouses; margin planks generally 8in in width, increased to 12in in width at the forward end of the deck. Teak planks beneath the electric winches, 3½in square.

Discharge from the waterways and raised roofs collected by scupper drains on the Boat Deck, piped along the deck head beneath and then down to the waterways at the sides of A Deck.

Steel decks within passenger staterooms and entrances, and in crew's quarters, covered with Harding's Litosilo.

Promenade Deck (A):

Channel waterway at sides of deck: 7in x .40in x 3in x 3in x .45in, inside flange sheared down to 2½in; fitted with teak gratings throughout. Scuppers arranged to avoid back-spray into promenades.

Where exposed to the weather, deck sheathed in 5in x 3in yellow pine; teak margin planks bordering all deckhouses, waterways, machinery footings, deck margins, and expansion joints – beveled around deckhouse bulkheads; margin planks generally 8in in width, increased to 12in in width at the forward end of the deck at the bulwarks.

Teak wood battens 3in x 1½in fitted on top of the wood planking around the perimeter of deckhouses to protect the bulkheads from marks left by deck chairs.

Steel decks within passenger staterooms and public rooms covered with Harding's Litosilo.

Bridge Deck (B):

13in-wide waterway at sides of deck where exposed to the weather, and in Café Parisien, private promenades, and First Class entranceways; bounded by 4in x 2½in x .40in angle bars along the deck margins (wide flange to deck); fitted with teak gratings throughout.

Where exposed to the weather, in Café Parisien, private promenades, and First Class entranceways, deck sheathed in 5in x 3in yellow pine; teak margin planks bordering all deckhouses, waterways, machinery footings, deck margins, and expansion joints – beveled around deckhouse bulkheads; margin planks generally 8in in width, increased to 12in in width at the forward end of the deck at the bulwarks.

Teak wood battens 3in x 1½in fitted on top of the wood planking around the perimeter of deckhouses in way of the Second Class promenades to protect the bulkheads from marks left by deck chairs.

Steel decks within passenger staterooms and public rooms covered with Harding's Litosilo.

Forecastle Deck:

8in-wide waterways at sides against the sheer strake, bounded by 3½in x 2½in x .40in angle bars along the deck margins (wide flange to deck); bounded by 6in-tall wash plates on the after end of the deck.

Deck sheathed in 5in x 3in pitch pine with teak margin planks; 10in x 4in teak around the windlasses and beneath the chain ramps, extending from No.1 Hatch forward, about 4ft wide; galvanized chequered-steel plate access cover between chain ramps, above windlass engines.

POOP DECK:

8in-wide waterways at sides against the sheer strake, bounded by 3½in x 2½in x .40in angle bars along the deck margins (wide flange to deck); bounded by 6in-tall wash plates on the forward end of the deck.

Deck sheathed in 5in x 3in pitch pine with teak margin planks. Two galvanized chequered-steel plate access covers aft of Docking Bridge above tiller for shipping the steering gear and capstan engines.

SHELTER DECK (C):

15½in-wide waterway at sides of deck where exposed to the weather, and within the Second Class enclosed promenade; waterways bounded by 4in x 3in x .44in angle bars along the deck margins (wide flange to deck); fitted with teak gratings within Second Class enclosed promenade; limber boards fitted over well deck waterways when required.

Teak margin planks throughout.

Well decks and Second Class enclosed promenade sheathed with 6in x 3½in pitch pine; beneath electric winches, deck sheathed with 5in x 3in teak.

Beneath Forecastle Deck: In port and starboard passageways in way of crew's messes, etc., and abeam of the No.1 Hatch, deck sheathed with 6in x 3½in pitch pine; in way of windlass machinery, deck sheathed with 4in-square teak; forward of collision bulkhead in way of wire-rope drum, deck sheathed with 3½in-square teak; bare steel deck from frame 146F to stem; steel deck in crew's messes and quarters covered with Harding's Litosilo.

Beneath Poop Deck: In steering engine space aft, 3½in teak under the steering gear, the remainder of compartment bare steel; steel deck in Third Class General and Smoke Rooms covered with Harding's Litosilo.

Between Bridge ends, steel decks within passenger staterooms and public rooms covered with Harding's Litosilo.

SALOON DECK (D):

Wooden gratings above bare steel deck in forward Store Room.

Loose planks laid in First and Second Class Galley Coal and Coke Spaces.

Steel decks within passenger staterooms and public rooms, and in crew's quarters covered with Harding's Litosilo.

UPPER DECK (E):

7in-wide waterways on port and starboard side the entire length of working crew passageway continuing aft to WTB L; 9in-wide waterways port and starboard along ship's side at all shell doors; waterways bounded by angle bars along margins – 3½in x 3in x .38in at sides of ship and along casings (wide flange to deck), and 3in x 3in x .38in along outboard side of the passageway.

In the working passages, and in the open spaces abaft the No.3 Hold, decks sheathed with 6in x 3½in pitch pine; margin planks also pitch pine.

Wooden gratings above bare steel deck in forward Store Room.

Steel deck within passenger staterooms and in crew's quarters covered with Harding's Litosilo.

MIDDLE DECK (F):

Wooden gratings above bare steel deck in forward Store Room.

Steel decks within passenger staterooms and public rooms, and in crew's quarters covered with Harding's Litosilo. Exceptions to above: the Swimming Bath compartment; all rooms but the Cooling Room of the Turkish Bath suite; Second Class accommodations aft over refrigerated spaces on G Deck below (wood sheathing beneath 'lino' tiles).

Lower Deck (G):

8in waterway port and starboard between frames 95F and 111F, bounded by 3½in x 3½in x .38in angle bars along margins; 8in waterway between frames 78F and 95F (port side only, and interrupted by the coal chutes), bounded by 3½in x 2½in x .38in angle bars along margins (wide flange to deck, 2½in flange sheared down to 1½in).

In refrigerated spaces, steel deck covered by 5in x 2½in pitch-pine planks laid on 3in x 2½in pitch pine battens; 5in x 2½in Oregon pine planking in the Meat and Poultry Rooms for the Restaurant; bare steel deck in the adjacent passageways.

Wooden gratings above bare steel deck in forward Store Room.

Steel deck within Squash Racquet Court, and in passenger staterooms and crew's quarters covered with Harding's Litosilo. Exceptions to above: Second and Third Class accommodations abaft refrigerated the spaces (wood sheathing beneath 'lino' tiles). Litosilo also laid in Post Office and Engineers' Store.
+In refrigerated spaces, steel deck covered by 5in x 2½in pitch-pine planks laid on 3in x 2½in pitch-pine battens.

Wooden gratings above bare steel deck in forward Store Room.

Notes

1. 'Litosilo' was a magnesite flooring composition which is explained later in this chapter.
2. One exception was the area of the Forecastle Deck in the area of the chain runs; here, teak planking was used.

Chapter 9

Temporary and Portable Accessways; Machinery and Boiler Casings; Hatches

Titanic's steelwork was nearly complete by the time she was launched and towed to the outfitting wharf. Provisions had been made within the nearly completed deck spaces and casings for shipping the engines, boilers, and other machinery that would be hoisted aboard using Harland & Wolff's huge floating crane. Steel decking and beams in certain areas were designed to be 'portable' (i.e., removable) to allow openings of sufficient size to permit the passage of the machinery to be fitted. Many of the transverse beams and plating that would otherwise have obstructed these openings had been trial-fitted but left uninstalled; more crucial members were temporarily bolted into place to provide strength to the hull during the launch.

Many of the strong transverse beams crossing the boiler and engine casings, such as those which spanned the Reciprocating Engine Room and actually passed between components of the erected engines, were designed to be temporarily removed. All of the portable plates, beams and structural members were designed to disturb as little as possible of the surrounding structure. Portable access plates were even present in the deck along the working crew passageway on E Deck. Here, the deck along the passageway was pierced by four hatches, provided for the lowering in and lifting out of furnaces from boiler rooms below during overhaul. Each of these hatches had a 5ft-square clear opening, and was covered by a galvanized chequered-steel access plate fitted flush with the surrounding wood deck sheathing.

Prior to the final stages of construction, an entire section of decking on the Boat Deck, including what would later become the flanking Tank Rooms and Engineers' Smoke Room, was left opened as a clear space for shipping the engines.

The engines, which had been fully completed in the Engine Works at Harland & Wolff and then partially broken down into large subassemblies, were transported to the outfitting wharf and lifted aboard. After the engine components and other machinery had been lowered in place and reassembled, the beams, deck plates and bulkheads forming casings were closed up and the steelwork of the surrounding deckhouse was completed.

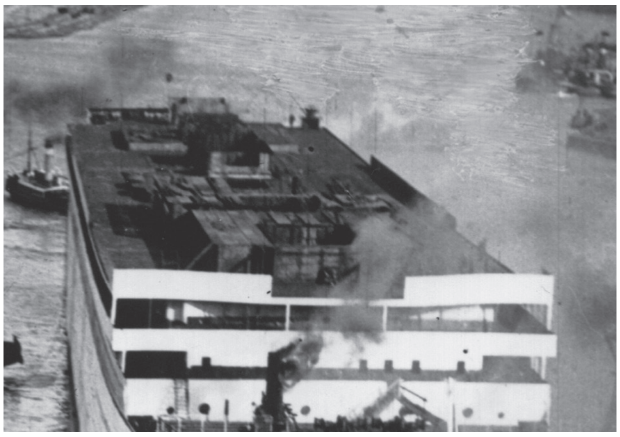


Fig. 9-1 ***Olympic* After Launch** – This image, cropped to emphasize the superstructure, shows the incomplete deckhouses, portions of which remained only partially built to allow the fitting of the boilers and engines.

Once the installation of the machinery, boilers, piping and uptakes had been completed, portable structural members were replaced and riveted to the adjoining steelwork. Fish plates were employed to join the ends of beam segments to the permanently installed portions; normal lap and butt seams were used in joining the steel plates.

Machinery casings

The reciprocating engine casing was located between the Nos 3 and 4 Funnels, just forward of the after First Class staircase. The casing above the Reciprocating Engine Room, like the shafts formed by the other machinery casings, was designated as 'light and air' space.

Ladders within these casings provided the engineers with a direct route to the higher decks. On the roof of the surrounding deckhouse, a skylight was constructed over the 24ft-long, 20ft-wide shaft to admit light and assist ventilation of the space below. The skylight contained eight large rectangular hatches – four per side – each fitted with a hinged weather-tight cover having four brass-framed

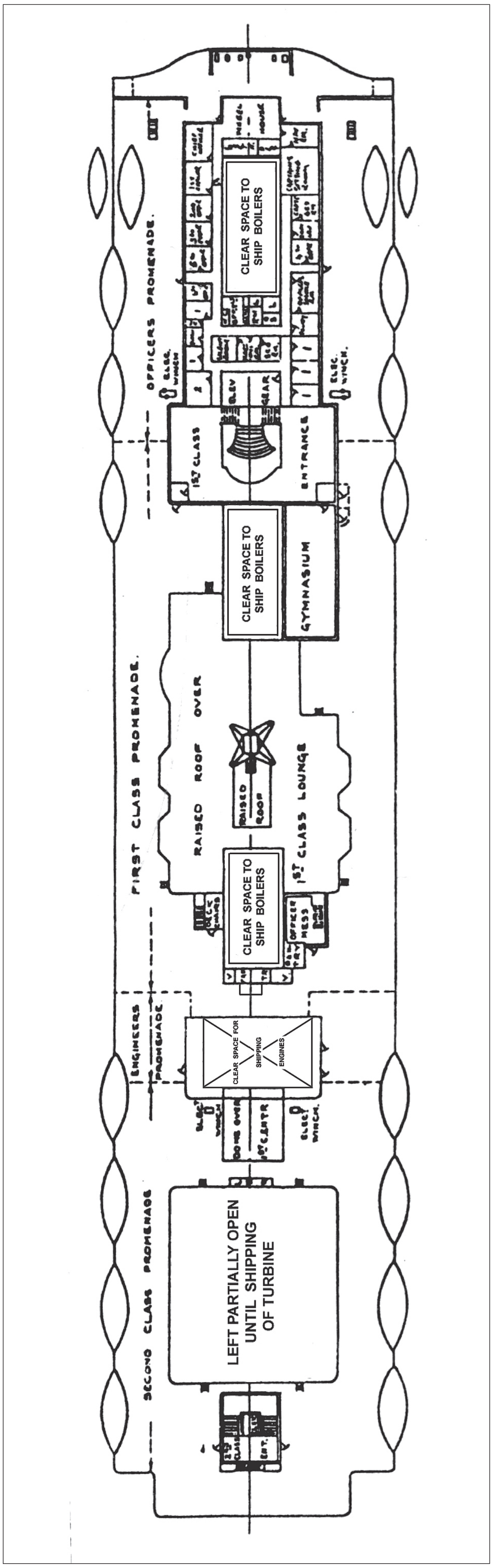

OFFICERS PROMENADE
CLEAR SPACE TO SHIP BOILERS
ELEC. WINCH
1ST CLASS
ENTRANCE
CLEAR SPACE TO SHIP BOILERS
GYMNASIUM
FIRST CLASS PROMENADE
RAISED ROOF OVER
RAISED ROOF
1ST CLASS LOUNGE
CLEAR SPACE TO SHIP BOILERS
OFFICER MESS
ENGINEERS PROMENADE
CLEAR SPACE FOR SHIPPING ENGINES
ELEC. WINCH
DOME OVER
1ST C. ENTR
ELEC. WINCH
SECOND CLASS PROMENADE
LEFT PARTIALLY OPEN UNTIL SHIPPING OF TURBINE
2ND CLASS
ENT.

Fig. 9-2 **Plan of Boat Deck** – A plan of the Boat Deck indicating the areas that were to remain open in order to provide a clear vertical pathway for shipping the engines and boilers.

bull's-eye lights. These covers could be manually raised or lowered as needed, and were actuated from beneath by hand cranks just as were the other skylights aboard the ship. At the level of E Deck, where the casing descended into the upper levels of the engine room, it was extended further out towards the sides of the ship, and also aft to the bulkhead separating the Reciprocating Engine Room from the Turbine Engine Room. Due to the height of the engines, the additional space afforded was necessary in order to provide space above the cylinders for lifting of the cylinder covers and pistons for examination and overhaul. There was, however, sufficient remaining space between the engines and the sides of the ship to allow a portion of F and G Decks to continue through the wings of the Reciprocating Engine Room on both sides of the casing.

Located within the after side of the reciprocating engine casing was a light-and-air shaft for the First and Second Class Galley which was, in effect, a ventilation trunk. Air was drawn by fans through a screen fitted over a large rectangular opening on the aft side of the reciprocating engine casing right above the after dome cover. This shaft also allowed for ventilation of the space within the dome cover via a duct led into it specifically for this purpose.

The casing beneath the No.4 Funnel was, in reality, part of a machinery casing, being the upper section of the casing above the Turbine Engine Room. This casing provided exhaust ventilation for air drawn from the Turbine Engine Room. The flue from the First and Second Class Galley was run up through the forward end of this casing where it was joined to a flue pipe within the No.4 Funnel.

Boiler casings; ventilation and fidley trunks

Casings were also located beneath the base of all four funnels. The boiler casings below each of the forward three funnels provided a clear shaft to the boiler rooms and stokeholds below. The casings extended below in unbroken length, and measured 46ft 6in long by 20ft wide inside the coamings from the house tops on the Boat Deck through the Saloon Deck (D); below this level, they were stepped outward across their length and breadth as they progressed further into the boiler rooms in order to clear the uptakes and boilers. In addition to enclosing the upper reaches of the boiler uptakes and the lower portion of the funnel, partitions within

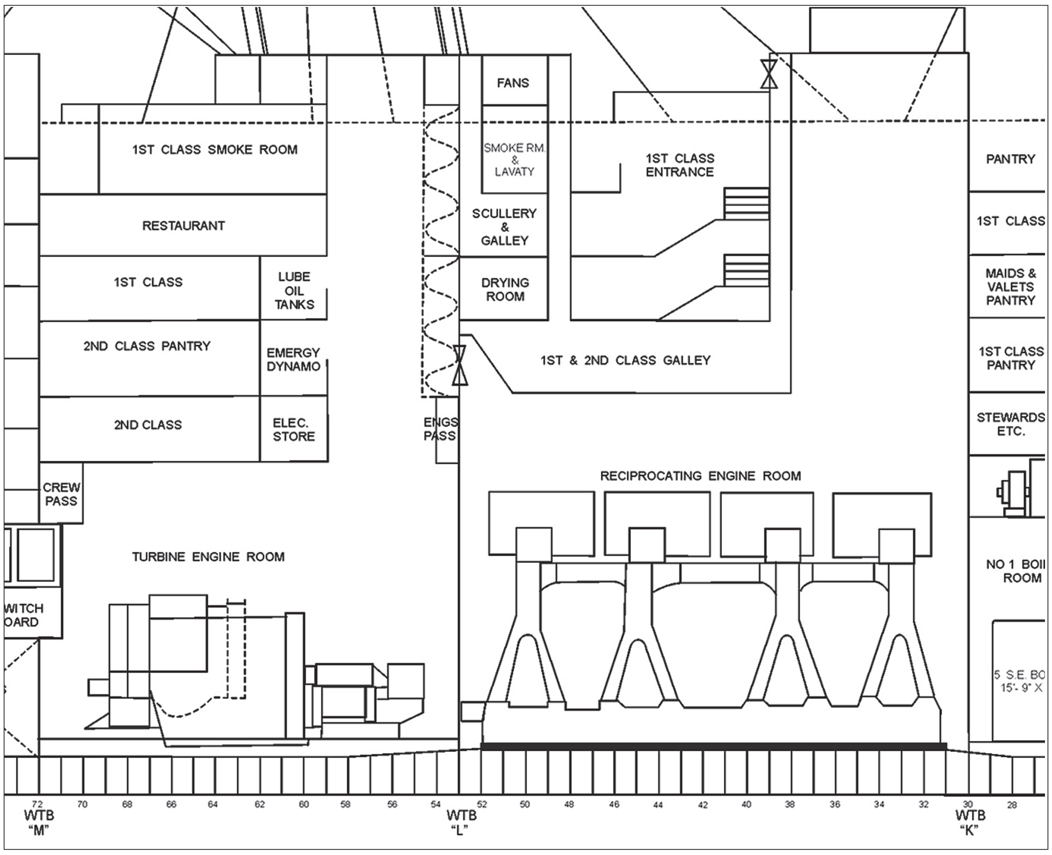

FANS
1ST CLASS SMOKE ROOM
SMOKE RM & LAVATY
1ST CLASS ENTRANCE
PANTRY
RESTAURANT
SCULLERY & GALLEY
1ST CLASS
1ST CLASS
LUBE OIL TANKS
DRYING ROOM
MAIDS & VALETS PANTRY
2ND CLASS PANTRY
EMERGY DYNAMO
1ST & 2ND CLASS GALLEY
1ST CLASS PANTRY
2ND CLASS
ELEC. STORE
ENGS PASS
STEWARDS ETC.
RECIPROCATING ENGINE ROOM
CREW PASS
TURBINE ENGINE ROOM
NO 1 BOI ROOM
WITCH OARD
5 S.E. BO 15'- 9" X
72 70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32 30 28
WTB "M"
WTB "L"
WTB "K"

Fig. 9-3 **Inboard profile – Reciprocating and Turbine Engine Casings.** *(Illustration by Bruce Beveridge)*

the forward and after ends of these casings formed the stokehold ventilation fan trunks and fidley trunks. The fidley trunks were required to exhaust heated air from the stokeholds. In *Titanic*'s case, the boiler casings were large enough to house hot-water tanks and other auxiliaries, while still being proportioned so as to be within the limits of the rules for calculating gross tonnage.

The fidley trunks were situated immediately fore and aft of each funnel in between the stokehold ventilation trunks and the funnel shaft. The fidley hatches were located at the tops of the casings at the base of the first three funnels, well above the passenger deck level. They were covered by grates and provided with solid sheet-iron storm covers which were put in place to cover the openings in extremely heavy weather and when the boilers

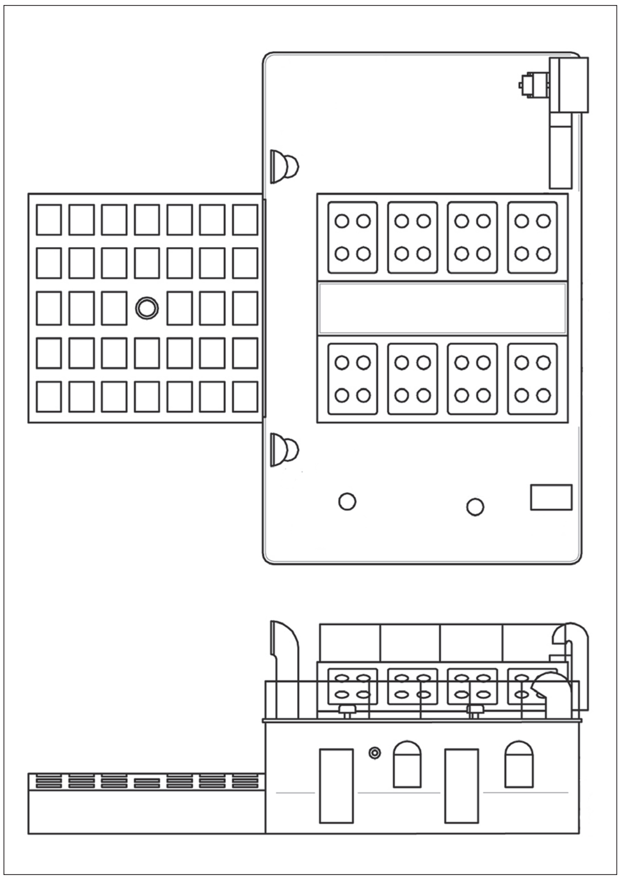


Fig. 9-4 **Reciprocating Engine Casing at Boat Deck level** – Plan view and starboard elevation of the deckhouse surrounding the Reciprocating Engine casing, on top of which was the large skylight for the Reciprocating Engine Room below. Abutting the casing on the aft side was the dome cover for the after First Class staircase, with a skylight fitted on top to admit natural light to the dome within. *(From the Hahn* Titanic *Plans/courtesy Robert Hahn)*

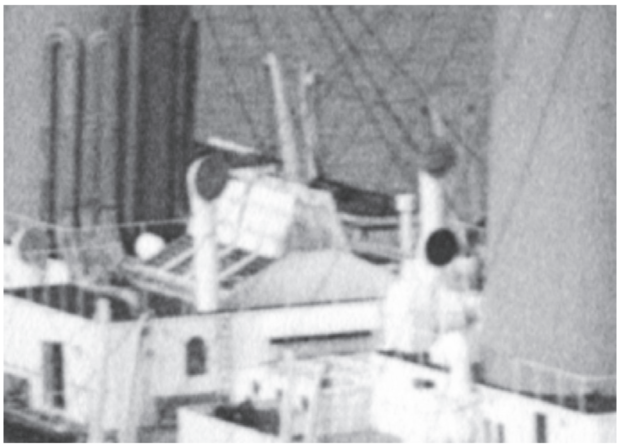


Fig. 9-5 **Reciprocating Engine Casing Skylight** – This photographic detail shows *Olympic*'s reciprocating engine casing skylight, photographed later in her career. Apparently it was a hot day because the covers are cranked wide open to allow maximum air circulation.

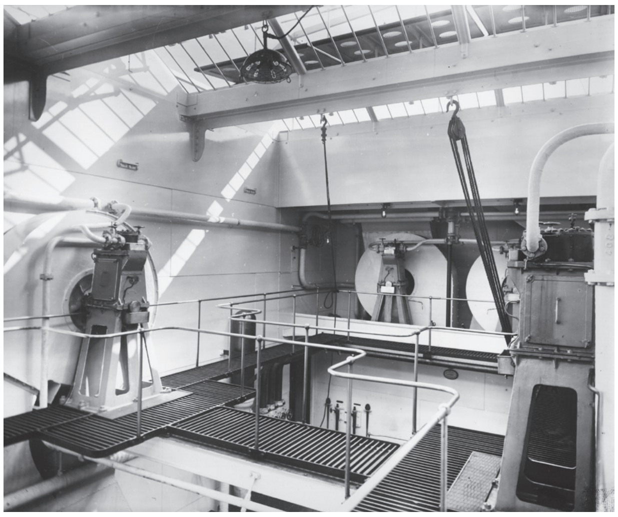


Fig. 9-6 **Engine Casing on *Oceanic*** – This image was taken inside the upper level of *Oceanic*'s engine casing, with the skylight and hatch covers in view. *Oceanic (II),* completed in 1899, was considerably smaller than *Titanic*, and there were fewer intervening decks between the cylinder tops and the skylight of the engine casing than in the *Olympic*-class ships.

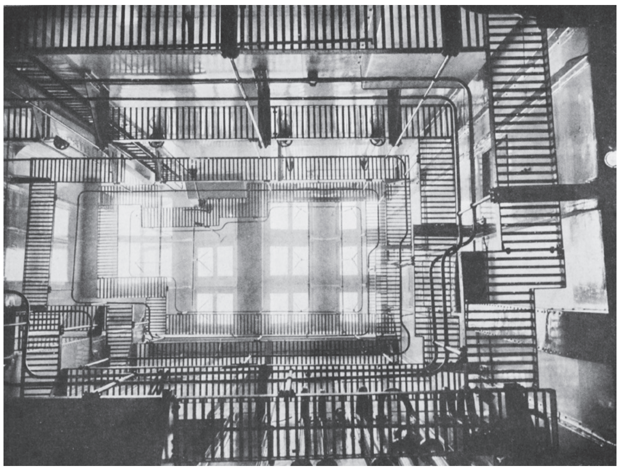


Fig. 9-7 **Reciprocating Engine Casing on *Mauretania*** – This image was taken aboard the Cunard Line's *Mauretania*, looking upward through the maze of platforms and ladders at each deck level. This photograph gives a clear impression of how *Titanic*'s reciprocating engine casing would have appeared to someone looking upward from the level of the cylinder tops. The turbine engine casing would not have appeared as well-lit from below, due to the absence of a skylight at the head of that casing. *(*Engineering*/Authors' collection)*

were not in use. The fidley trunks served a number of purposes in addition to ventilation. They provided a clear passage for low-pressure steam supply and condensate return pipes for the heating and hot water auxiliaries. They also contained ladders and platforms which provided the engineers access to the aforementioned auxiliaries as well as providing those working in the boiler spaces with a direct emergency escape route to the Boat Deck.

The plating of the sides and ends of the casings was formed of steel sheets of between .26 and .34in thick and single-riveted edgewise. Above the level of the Bridge Deck (B), the sides of casings were built in horizontal strakes, while vertical plates were used below this level. Vertical bulb-angle stiffeners were attached to the interior surfaces of the plating, with 4in x 2½in x .30in being used from the house tops to the level of the Bridge Deck (B), at which point an increase to 5in x 2½in x .38in was made. These relatively light stiffeners were joggled to allow the sheet steel strakes of the casings to be attached directly. Insulation was installed between the casings and the interior joinery to shield the surrounding accommodation areas from the terrific heat radiated from the uptakes and funnels. The corners of the openings in the decks through which the boiler casings passed were rounded rather than sharp, having a 12in radius.

The tops of the casings beneath the funnels were formed by a flat, sheet-steel roof supported by light bulb-angle beams fitted between and around the opening for the funnel. The supporting angles were bracketed to the vertical stiffeners of the casing. The tops of the casings stood 9ft 6in above the height of the Boat Deck. The top of the casing beneath the No.1 Funnel was raised above the height of the wooden decking on top of the Officer's Quarters deckhouse by about 15in; a raised casing such as this was commonly referred to as a 'fidley deck'. The casing beneath the No.1 Funnel was the only one that extended above the height of the surrounding wooden decking. The tops of the remaining casings, including that beneath the No.4 Funnel, were flush with the surrounding steel deck plating of the deckhouse tops. In the locations where wood decking was laid near the casings, it was stopped at the perimeter and was not laid over the tops; this was due to the fact that the wood was incapable of withstanding the heat given off near the bases of the funnels.

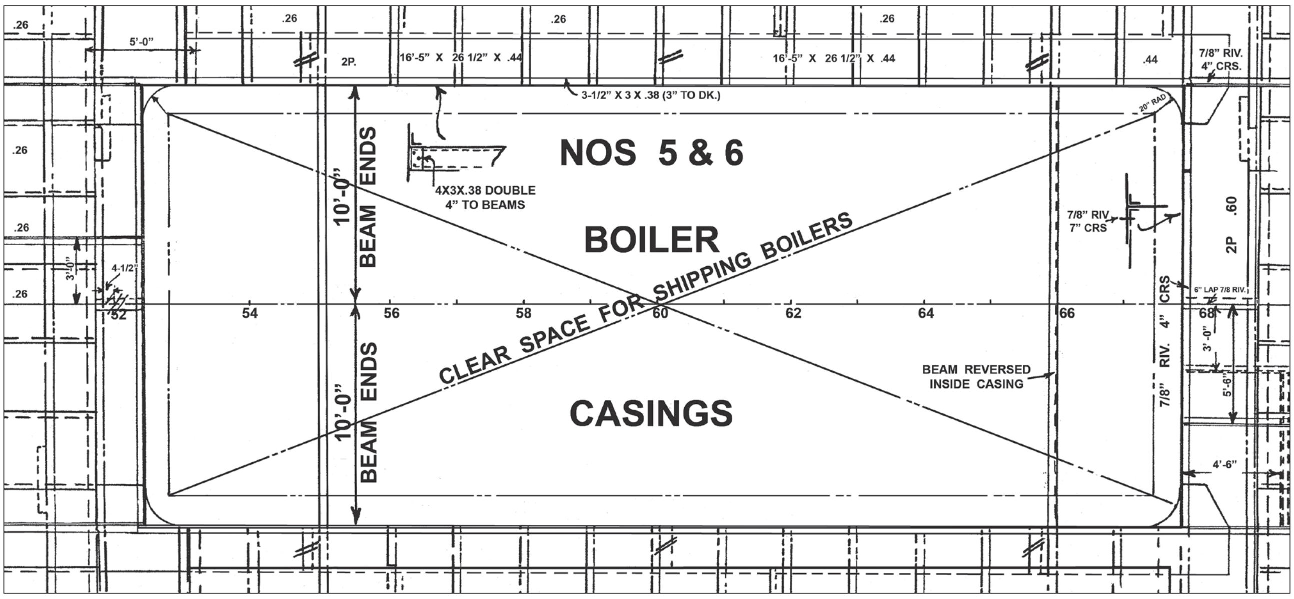

.26
5'-0"
2P.
16'-5" X 26 1/2" X .44
3-1/2" X 3 X .38 (3" TO DK.)
.44
7/8" RIV. 4" CRS.
20" RAD
NOS 5 & 6
BOILER
CASINGS
CLEAR SPACE FOR SHIPPING BOILERS
10'-0" BEAM ENDS
4X3X.38 DOUBLE 4" TO BEAMS
7/8" RIV. 7" CRS
2P .60
6" LAP 7/8 RIV.
7/8" RIV. 4" CRS
3'-0"
5'-6"
4'-6"
4-1/2"
BEAM REVERSED INSIDE CASING
52
54
56
58
60
62
64
66
68

Fig. 9-8 **Boiler Casing** – Plan view – The Nos 5 & 6 Boiler casing and surrounding structure at the level of A Deck. *(Illustration by Bruce Beveridge based on original H&W Promenade Deck Iron plan)*

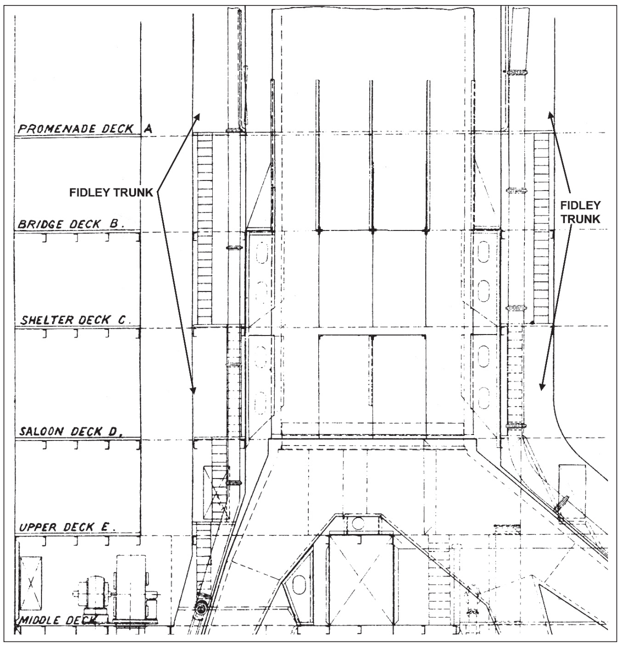

PROMENADE DECK A
FIDLEY TRUNK
BRIDGE DECK B.
SHELTER DECK C.
SALOON DECK D.
UPPER DECK E.
MIDDLE DECK
FIDLEY TRUNK

Fig. 9-9 **Fidley Trunks** – This longitudinal section through the Nos 1 & 2 Boiler Casing shows the position of the fidley trunks. The main function of these trunks was to vent the hot air rising from the boiler rooms, but the space was also utilized to house hot-water tanks, auxiliary steam pipes and the escape ladders from the stokeholds. *(*The Shipbuilder*/Authors' collection)*

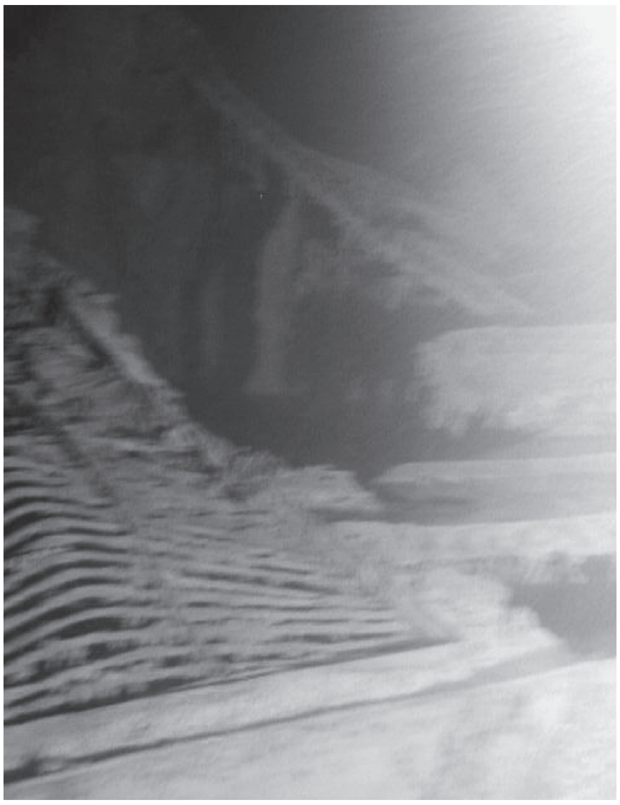


Fig. 9-10 **Area Around No.1 Funnel** – This image from *Titanic*'s wreck shows one of the fidley gratings at the base of where the No.1 Funnel once stood. The gratings seen here were common iron foot grates of the type fitted throughout the working areas of the ship. *(Steve Rigby collection)*

Cargo hatches

Titanic had six holds that were accessed through seven hatchways. The hatchways were constructed with corners having a 12in radius where not affected by trunking, as these were found to be far less prone to fatigue and fractures than sharp corners. The hatch coamings on the weather decks were peaked longitudinally except for the No.1 Hatch on the Forecastle Deck, which had a rounded steel cover, and the two No.4 Hatches at the after end of the Bridge Deck (B). By regulations, the minimum permitted height for hatch coamings on unenclosed decks was 24in when within one-fourth of the length of the vessel from the bow, and a minimum of 18in-high aft of this.

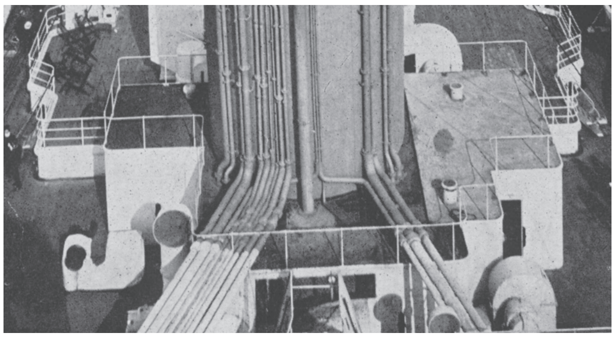


Fig. 9-11 **Top of Nos 1 & 2 Boiler Casing** – This unique view from the top of the No.4 Funnel is looking down on the top of the casing at the base of the No.3 Funnel aboard *Olympic* in 1913. The perimeter of the rectangular casing top can be clearly distinguished from roofs of the surrounding deckhouse on either side. The grates above the fidley trunk for the No.1 Boiler Room are just visible beneath the water pipes; the starboard grating is partially obstructed by a metal cover.

In order to strengthen the hatch coamings against the forces of seas shipped in heavy weather, a number of temporary ties were inserted to join the port and starboard coamings together. Located inside the coamings of each hatch were portable web beams; these extended the full width of the opening and were lightened with holes to reduce the effort necessary to move them in and out of position. They were attached to the coaming with nuts and bolts passing through double vertical angle bars fitted to the insides of the coamings. The web plate beams were placed at such a height as to just bear the weight of the hatch covers. Longitudinal beams called 'fore-and-afters' were not used on the *Olympic*-class liners as these were deemed unnecessary due to the close spacing of the web beams and the strengthening of the hatchways as the result of fitting pillars below. The minimum spacing for the athwartship web beams was typically 4ft with a maximum of no greater than 5ft. In order to meet the spacing requirements, three of these portable web beams were provided across the No.2 Hatch in the forward Well Deck – this being the largest hatch of all – while two web beams were fitted across the Nos 3 and 5 Hatches in the forward and after Well Decks, respectively. Because of the relatively short span of the Nos 4 and 6 Hatches, only a single portable web beam was required across each opening.

Weather deck hatch coverings

Titanic utilized a combination of solid and grated hatch covers. These covers were basically inserts fitted within the tops of the coamings which were supported in the center by the portable web beams. They were made of pitch-pine planks averaging 3in in thickness. The covers were made a maximum of 24in in width to ensure that they would not be too heavy to handle. Each of the solid covers was fitted with two lifting bars let flush into the top surface and secured by through-bolts; a cup-shaped opening 5in in diameter was drilled out of the wood beneath the bar to provide a receptacle for the hand. The covers fit across the top edges of the hatch coamings, which were made of rolled section, and rested within the ledges. The ledges were mitered at the corners and of sufficient depth to house the wooden covers.

Titanic's hatches were made weathertight externally by stretching two layers of heavy canvas tarpaulins over the wooden covers and coamings. The canvas covered the entire upper surface and extended for some distance down the sides of the coaming, where it was tightly clamped by batten bars and wedges.

The batten bars were flat, galvanized-iron bars, about 2½in x ⅜in, completely encircling the hatchway. The butts were kept away from the corners, the bars being bent around these to ensure snug fitting of the tarpaulin. The bars, which pressed the canvas to the coaming, rested within the hatch battening cleats. The cleats were cast steel and fastened to the coaming with ¾in rivets.

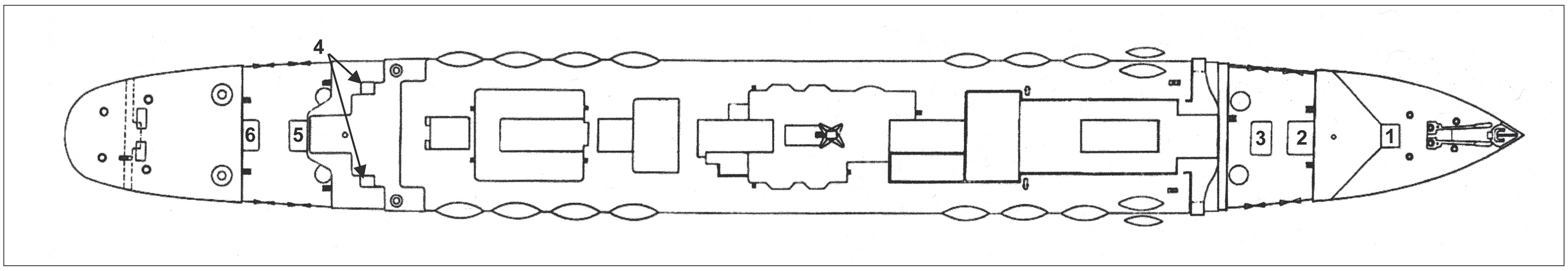


Fig. 9-12 **Cargo Hatch Locations and Designations**.

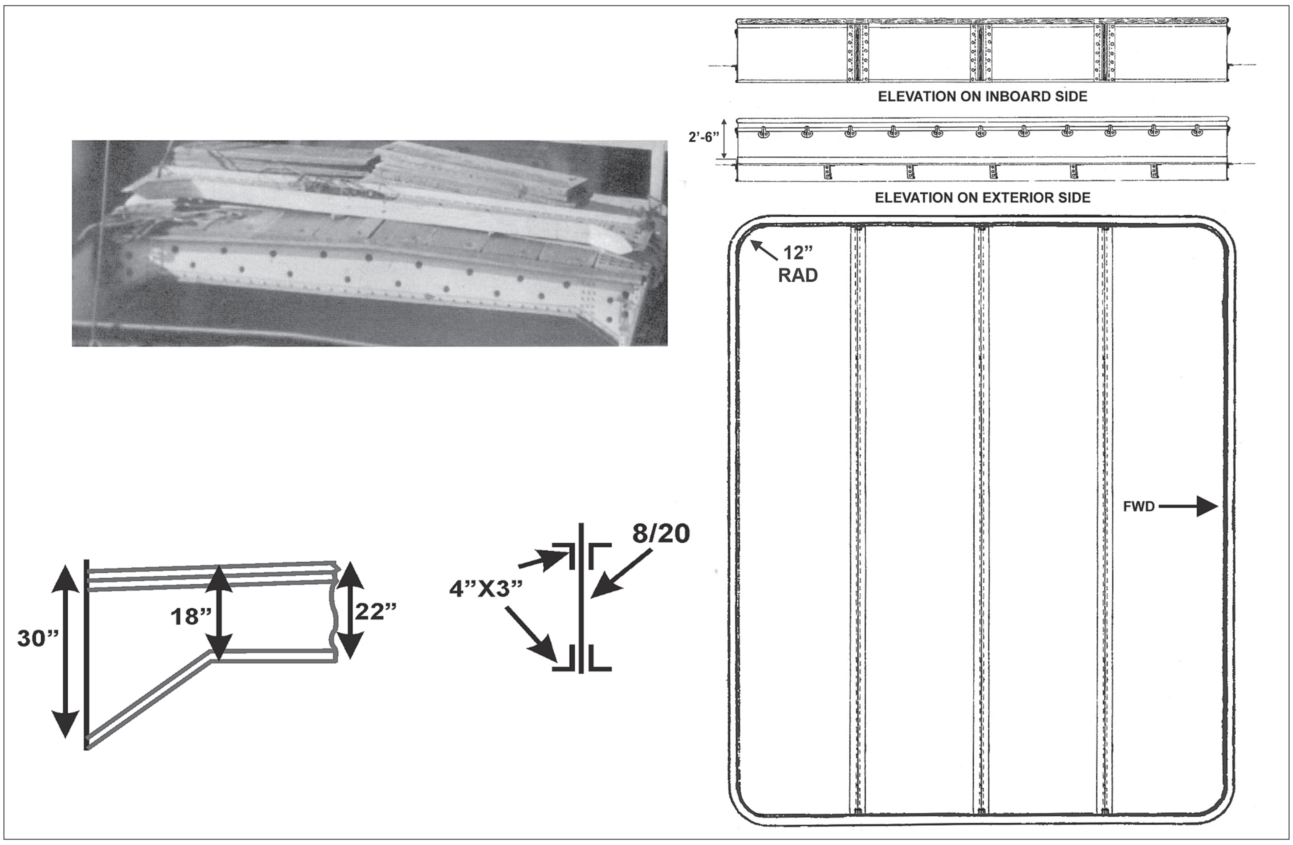


Fig. 9-13 **Portable Web Beams and Coaming Details** – The image at upper left shows a portable web beam lying across the partially covered No.2 Hatch; the solid and grated covers it would support when installed lay stacked immediately forward of the beam. The drawing at lower left illustrates the principal dimensions and structural make-up of the portable web beams of the Nos 2, 3, 5 and 6 Hatches. At lower right is a plan view showing portable web beams fitted between the port and starboard coamings of the No.2 Hatch; in this instance there were three, the total number required depending on the longitudinal span of each hatch. At upper right, the inboard elevation of the coaming shows the arrangement of double angle-bar supports which served to locate each beam and hold it upright, while the outboard elevation shows both the hatch batten cleats along the upper edge of the coaming, and also the manner in which the coaming extended below the level of the steel deck. *(Illustrations by Bruce Beveridge; image from authors' collection)*

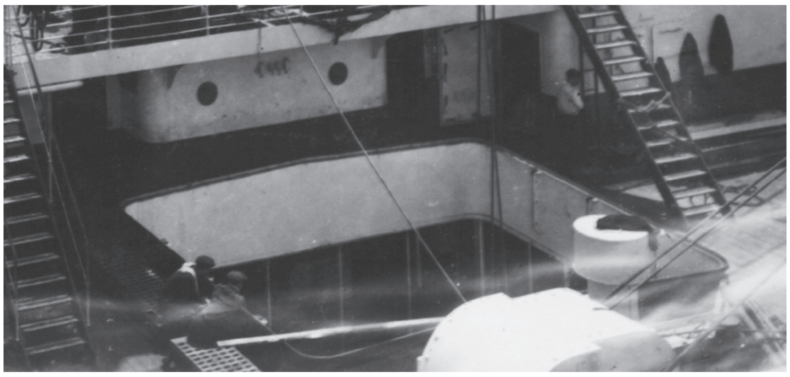


Fig. 9-14 **No.2 Hatch** – In this 1911 image looking forward into *Olympic*'s No.2 Hatch, the double angle-bar supports in which the portable web beams rested can be seen on the inboard face of the starboard coaming.

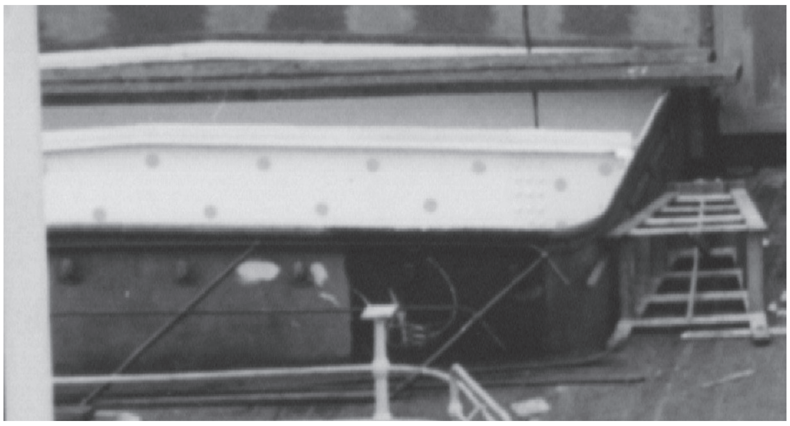


Fig. 9-15 **No.6 Hatch** – The No 6 hatch of *Olympic*, photographed during the final months of construction. Midway between the forward and after coamings, a portable web beam can be seen. Lying in front of the coaming is a railing from a deck ladder. The cleats for the batten bars can also be seen along the top edge of the coaming. *(H&W/Authors' collection)*

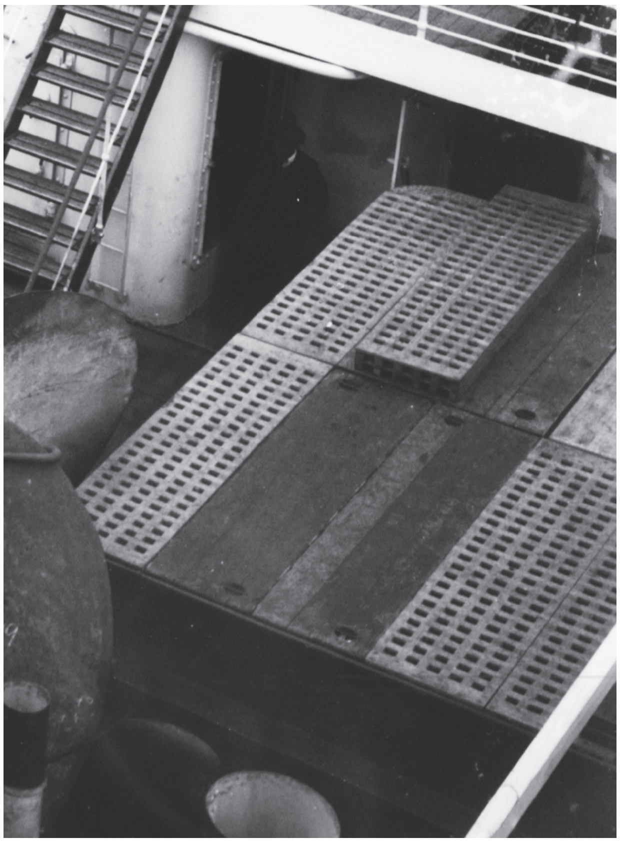


Fig. 9-16 **No.2 Hatch Showing Grated Hatch Covers** – The No.2 Hatch of *Olympic* taken right after the postwar refit. During the major refit following *Titanic*'s loss, the height of the hatch coamings along the Shelter Deck (C) were raised significantly, but the original grated and solid hatch covers were retained. Along the periphery of the hatch, the covers rested in ledges formed in the patent hatch-rest bars riveted to the perimeter of the coaming, and were supported in the center by the portable web beams. *(H&W/Authors' collection)*

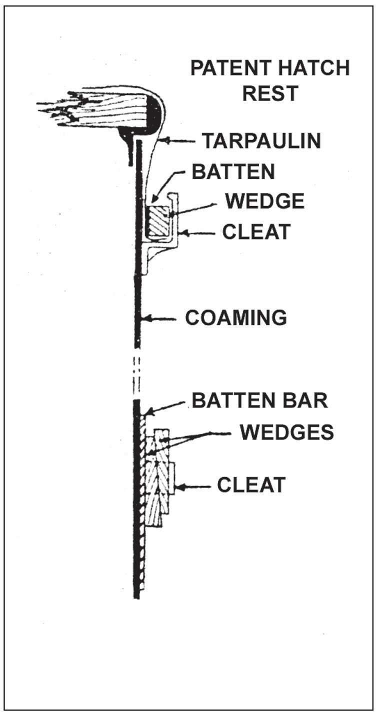

PATENT HATCH REST
TARPAULIN
BATTEN
WEDGE
CLEAT
COAMING
BATTEN BAR
WEDGES
CLEAT

Fig. 9-17 **Illustration of Batten and Wedge** – These sectional drawings through a coaming illustrate the arrangement of battens, wedges and cleats used to hold the tarpaulins and hatch covers in place. Also shown is the form of the patent hatch-rest bars which rimmed the tops of the coamings. *(Illustration by Bruce Beveridge)*

The cleats, spaced about 15in apart, were far enough down from the edges to provide easy fitting of the canvas. When the batten bars and canvas were arranged for sailing, the whole was secured by driving oak or elm wedges between the hook of the cleat and the bar. The canvas tarpaulins were removed in good weather, with the grated wooden covers allowing natural ventilation for the lower decks.

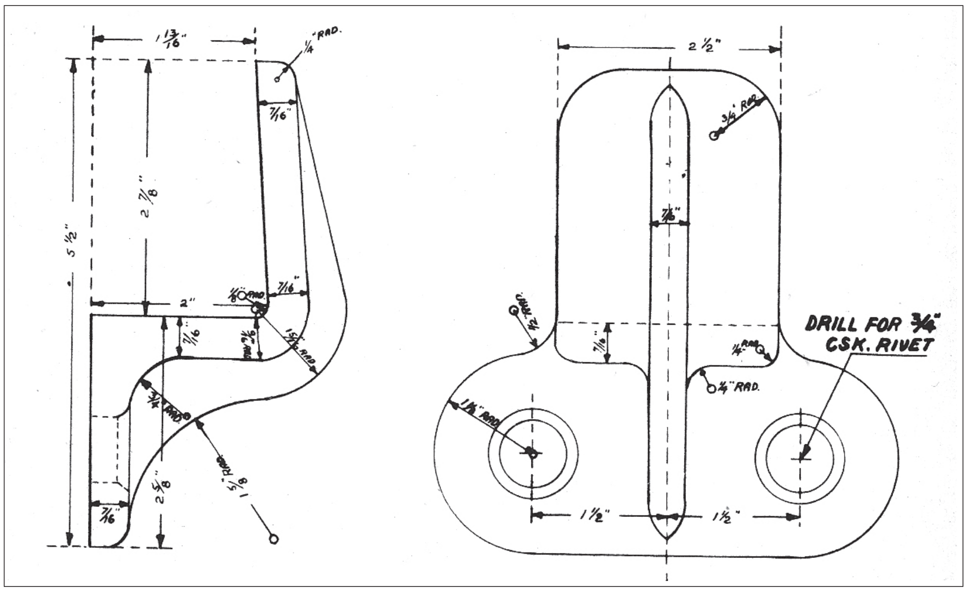

1 13/16"
1/4" RAD.
7/16"
2 7/8"
5 1/2"
2"
1/8" RAD.
7/16"
7/16
15/16" RAD.
3/4" RAD.
2 5/8"
1 5/8" RAD.
7/16"
2 1/2"
3/4" RAD.
7/8"
1/2" RAD.
7/16"
1/4" RAD.
1/4" RAD.
1 1/4" RAD.
DRILL FOR 3/4" CSK. RIVET
1 1/2"
1 1/2"

Fig. 9-18 **Hatch Batten Cleat** – Details of a common form of batten cleat used on ships of the era.

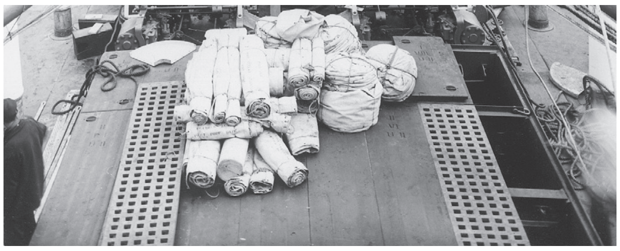
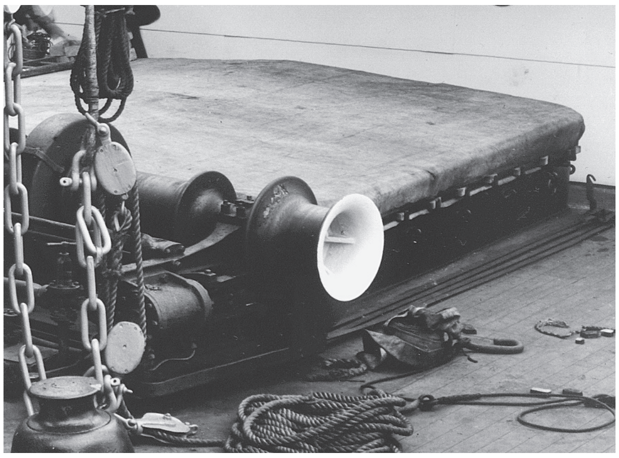


Fig. 9-19 **Cargo Hatch on *Mallina*** – This is an image of a cargo hatch on the Harland & Wolff-built steamship *Mallina*, hull No.407, delivered in 1909 to the Australasian United Steam Navigation Co. Both the solid and grated hatch covers can be seen, as well as the patent hatch-rest bars. *(H&W/Authors' collection)*

Below Fig. 9-20 **Hatch Cover Secured on *Rotterdam*** – Another image showing one of the *Rotterdam*'s hatch covers. In this case, the covers and tarpaulin have been secured by the batten bars which have been wedged home in the cleats. *(H&W/Authors' collection)*



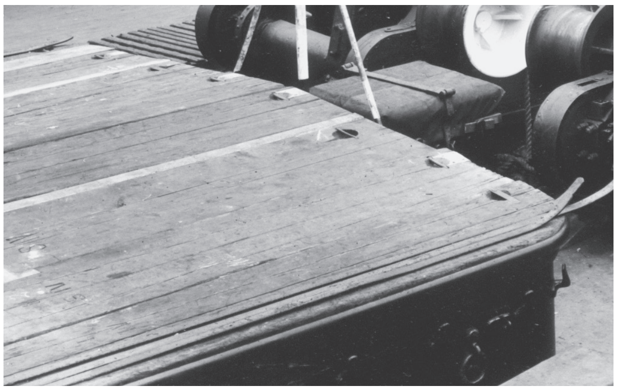


Fig. 9-21 **Hatch Cover on *Rotterdam*** – The *Rotterdam* was Harland & Wolff Hull No.390, completed for the Holland America Line in 1908. This view of one of the hatch covers shows the solid covers, with batten bars lying along the edge. *(H&W/Authors' collection)*

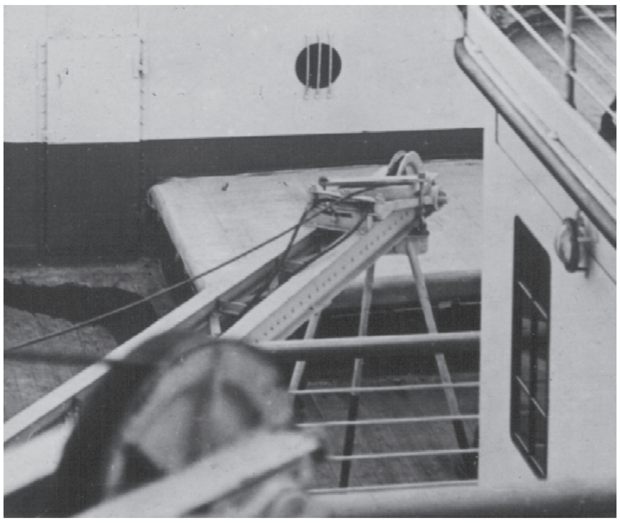


Fig. 9-22 **No.6 Hatch on *Titanic*** – *Titanic*'s No.6 Hatch, partially obscured by the deckhouse enclosing the after Second Class Entrance on B Deck. The hatch is seen here with the covers on and the tarpaulin battened down.

Trunk hatchways

A trunk hatchway is one on which the coaming plates of the different decks are united by a casing or trunk. These were fitted on passenger vessels so that when a hatchway was opened to work cargo in the hold, the passenger accommodation in the 'tween decks was unaffected by the operation. However, on *Titanic*, the majority of the hatchways through passenger accommodations had at least one side exposed to the compartment. In some areas of the ship, namely the open spaces of Third Class, hatchway openings were fitted with portable web beams designed to take wooden covers like those mentioned above. These covers generally formed a platform above the deck level, as they were secured within coamings, the lowest of which were formed by 8in-tall bulb angles. A number of the lower deck hatch coamings were taller than this, while in one location – the No.2 Hatch at the Orlop Deck level – the hatch cover and coaming were completely flush with the surrounding deck; here, the reinforced cover provided additional flush deck space within a hold intended for the stowage of motorcars. In the areas where the hatchway was only partially trunked, patent hatch rest pieces were fitted to take the covers. One set of waterproof tarps was provided for each hatch at the Saloon (D), Upper (E), Middle (F), and Lower (G) Decks. Canvas hatch covers, when utilized in passenger areas, were bleached for appearance.

In instances where the hatchways were open to the deck, the openings were protected with portable stanchions and chains, or with vertical-bar gratings giving the appearance of jail bars. These gratings were of the same design as the fold-down gratings used to protect the interior openings of the gangway doors, etc. They were made of 2in-diameter tubes spaced 6in apart center-to-center, shipped through ½in-thick galvanized iron plates. Bar gratings of this design aboard *Titanic* were used predominantly where the No.1 Hatchway passed through the quarters of the Firemen and Trimmers.

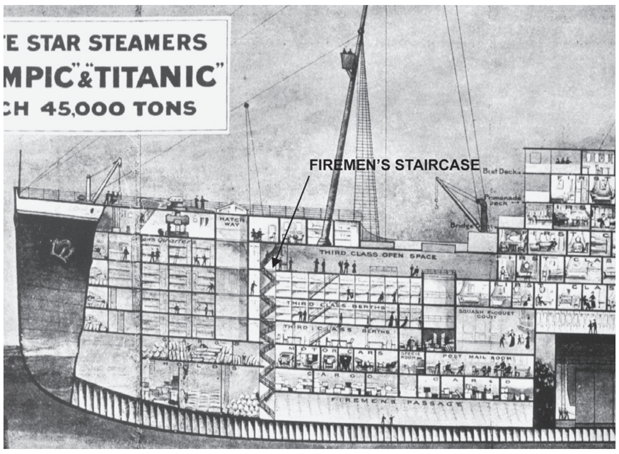


Fig. 9-23 **Illustration of Firemen's Staircase and Tunnel** – The Firemen's staircase and Firemen's Tunnel as seen in a period illustration showing a cutaway of *Olympic* and *Titanic*. Although not apparent here, there were two staircases located side-by-side; one was for upward movement and the other for downward movement.

(Only one instance of such bar gratings being fitted in a passengers' area appears on the General Arrangment plan, this being the port side of the No.5 Hatch on E Deck, in Section M of the Third Class accommodations.) The fitting of protective bars and grate hatch covers allowed air circulation from above while keeping people clear of the opening. Occasionally, one or more sides of a hatch opening were completely sealed by a steel bulkhead; this was the case if another compartment abutted the hatch opening. Runged ladders were also fitted between decks within trunked hatchways.

Hatch covers on decks which allowed access to cargo or baggage were secured with metal straps secured with Yale locks. The trunks for the No.3 Hatch at G Deck and the Orlop Deck were fitted with double steel doors port and starboard to allow a 5ft securable opening at either side; additionally, a door into the Specie Room was fitted through the forward bulkhead of this trunk at the Orlop Deck level. A double steel door was also fitted at the level of G Deck through the inboard side of the trunk around the port No.4 Hatchway.

Firemen's Tunnel

The Firemen's Tunnel, which provided a passageway between the boiler rooms and the spiral stairs leading to the quarters of the firemen, greasers and trimmers, was located between frames 78F and 112F; it is also noted on certain drawings as either the 'pipe tunnel', or 'steam pipe tunnel' because, in addition to the bilge and ballast piping beneath the walkway, the steam supply and exhaust return pipes for the forward capstan, windlass and winch engines were run along the overhead within this passageway. The plate strakes which enclosed the tunnel were horizontal, and the edges and butts of the plating were lapped and double riveted. The seams were joggled. Channel stiffeners were fitted on the inside, one frame space apart.

Deck plates were fitted 2ft 7½in above the Tank Top starting at the base of WTB B and extended aft along the entire length of the tunnel to provide a level walking surface clear of the bilge and ballast piping which ran over the Tank Top plates within this space. These deck plates consisted of two widths of chequered plate flanged on the outboard edges and resting on athwartship angle bearers.

Along the center of the tunnel were stanchions placed at 6ft intervals supporting a tube handrail; this divided the tunnel along its length so that one side could be used for entering and the other for leaving the boiler rooms. The semicircular top of the tunnel was insulated to the depth of the stiffeners which were fitted on the inside. The insulation was covered by light sheet iron plates which were attached by bolts to the channel stiffeners.

Hatches on Weather Decks

NO.1 HATCH

The No.1 Hatch was located on the Forecastle Deck between frames 116F and 121F, and measured 11ft 11in in length and 13ft 11in in breadth inside the coaming. The coaming stood 2ft 6in above the wooden deck, had rounded corners and was strengthened by brackets. The forward brackets (two on each side port and starboard and three forward) were covered by a steel plate mounted at a 45° angle. The plate created an angled breakwater to help protect the fore end of the hatch from stresses brought on by green seas shipped over the bow. The cover was made of steel and fitted with four round bull's-eye lights on the top surface, positioned athwartship aft of the athwartship centerline. The top of the hatch had two hinged covers (port and starboard) for easy access. The hatchcover was held down by the use of bolts which fastened within special clamps located on the coaming.

NO.2 HATCH

The No.2 Hatch was located in the forward Well Deck between frames 95F and 101F; it measured 16ft 5in in length and 19ft 11in in breadth inside the coaming, and was constructed and covered for watertightness as described previously. The coaming stood 2ft 8in

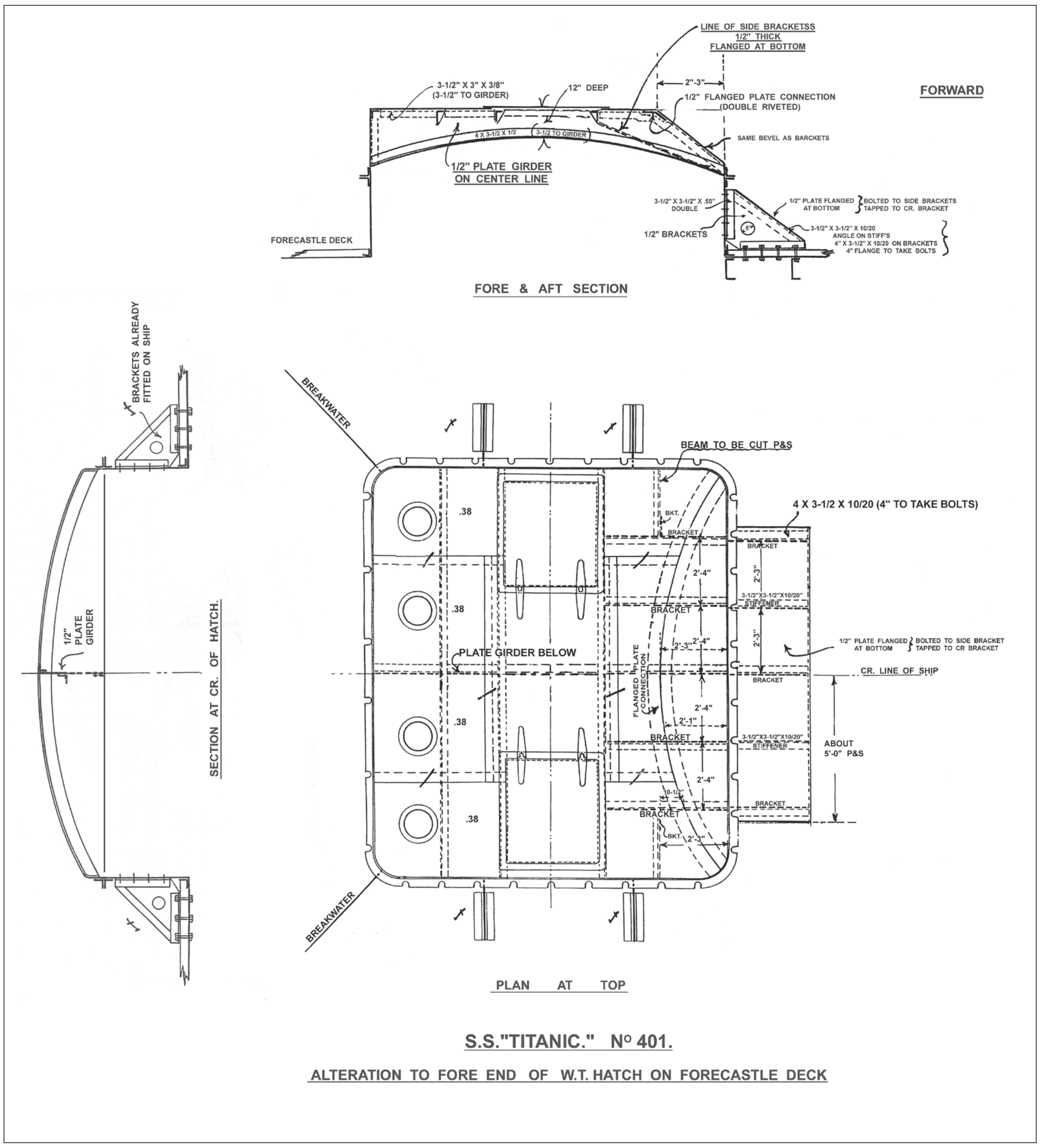

LINE OF SIDE BRACKETSS
1/2" THICK
FLANGED AT BOTTOM
3-1/2" X 3" X 3/8"
(3-1/2" TO GIRDER)
12" DEEP
2"-3"
1/2" FLANGED PLATE CONNECTION
(DOUBLE RIVETED)
FORWARD
4 X 3-1/2 X 1/2
3-1/2 TO GIRDER
SAME BEVEL AS BARCKETS
1/2" PLATE GIRDER
ON CENTER LINE
3-1/2" X 3-1/2" X .50"
DOUBLE
1/2" PLATE FLANGED
AT BOTTOM
BOLTED TO SIDE BRACKETS
TAPPED TO CR. BRACKET
3-1/2" X 3-1/2" X 10/20
ANGLE ON STIFF'S
4" X 3-1/2" X 10/20 ON BRACKETS
4" FLANGE TO TAKE BOLTS
5"
1/2" BRACKETS
FORECASTLE DECK
FORE & AFT SECTION
BRACKETS ALREADY
FITTED ON SHIP
1/2"
PLATE
GIRDER
SECTION AT CR. OF HATCH.
BREAKWATER
BEAM TO BE CUT P&S
4 X 3-1/2 X 10/20 (4" TO TAKE BOLTS)
.38
BKT.
BRACKET
2'-4"
2'-3"
3-1/2"X3-1/2"X10/20"
STIFFENER
PLATE GIRDER BELOW
FLANGED PLATE CONNECTION
1/2" PLATE FLANGED
AT BOTTOM
BOLTED TO SIDE BRACKET
TAPPED TO CR BRACKET
CR. LINE OF SHIP
2'-1"
ABOUT
5'-0" P&S
10-1/2"
PLAN AT TOP
S.S."TITANIC." N° 401.
ALTERATION TO FORE END OF W.T. HATCH ON FORECASTLE DECK

Fig. 9-24 **No.1 Hatch Cover and Coaming on *Titanic*** *(Illustration by Bruce Beveridge based on original H&W drawing)*

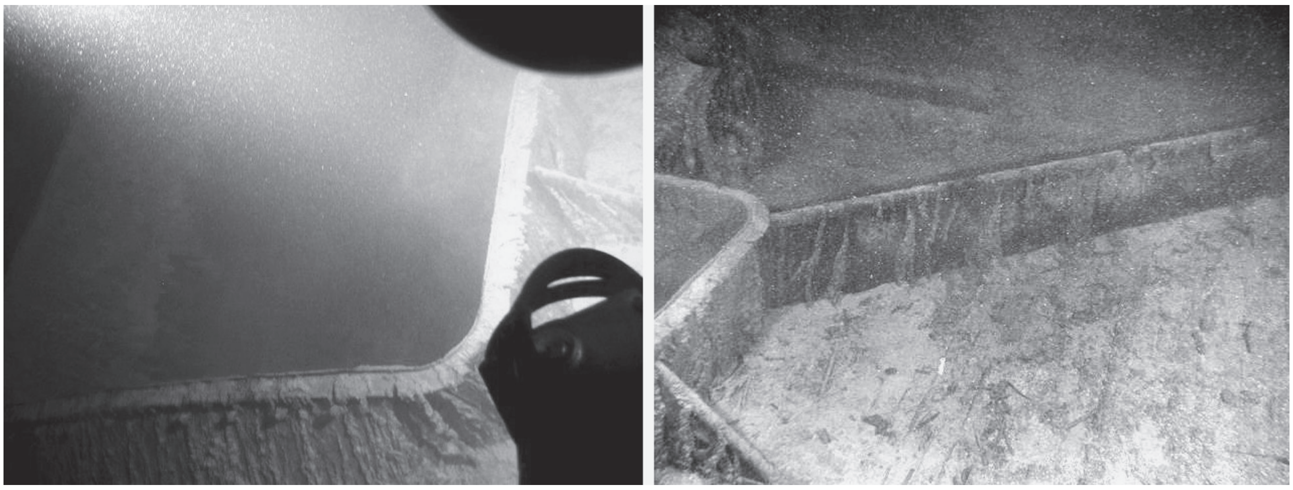


Fig. 9-25 **No.1 Hatch Coaming on *Titanic*'s Wreck** – Two images of the No.1 Hatch coaming on *Titanic*'s wreck. At right, looking to starboard from the after port corner of the hatch, the long breakwaters on the Forecastle Deck can be seen trailing aft (to the right of the photo) from the after corners of the hatch coaming. At left, as seen from ahead and slightly to port, one of two angle gussets which stiffened each of the sides of the coaming can be seen, while the sloped breakwater added to the forward coaming is visible at the bottom of the image. This latter feature was one of many changes made during *Titanic*'s fitting-out based on operational experience gained from the *Olympic*. This particular change was made to avoid a repeat of an incident in which the No.1 Hatch cover was torn from the coamings and hurled aft as *Olympic* pushed ahead through tremendous seas during a January 1912 storm. *(Both images Steve Rigby collection)*

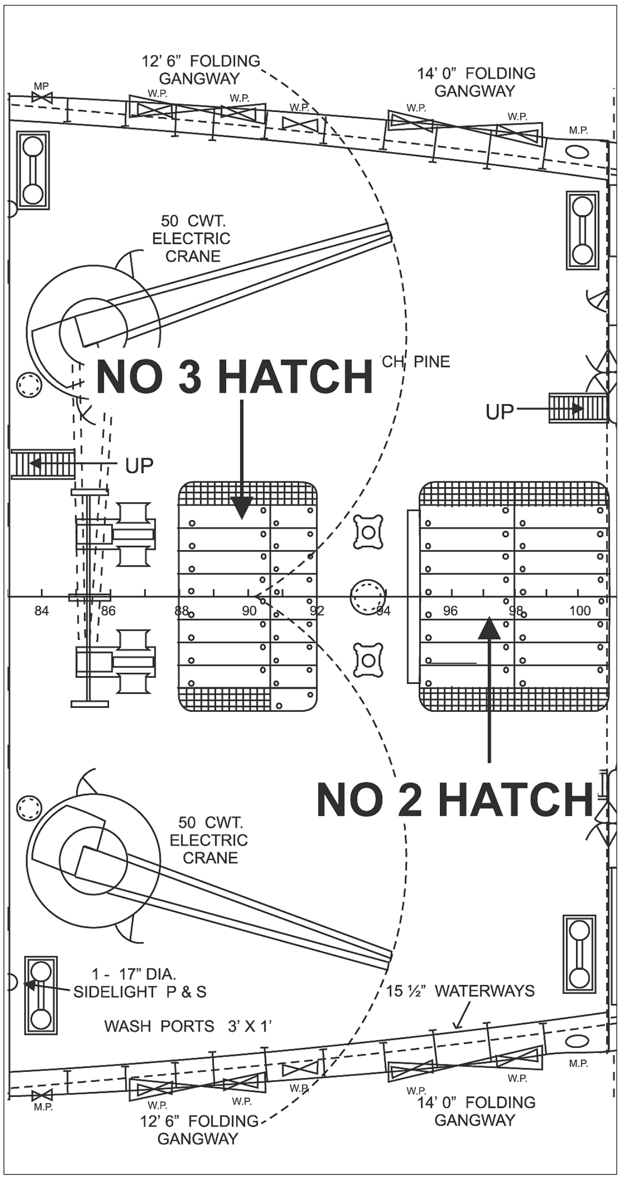

12' 6" FOLDING GANGWAY
14' 0" FOLDING GANGWAY
MP
W.P.
M.P.
50 CWT. ELECTRIC CRANE
NO 3 HATCH
CH. PINE
UP
UP
84
86
88
90
92
94
96
98
100
NO 2 HATCH
50 CWT. ELECTRIC CRANE
1 - 17" DIA. SIDELIGHT P & S
15 ½" WATERWAYS
WASH PORTS 3' X 1'
12' 6" FOLDING GANGWAY
14' 0" FOLDING GANGWAY

Fig. 9-26 **Nos 2 and 3 Hatch Locations.** *(Illustration by Bruce Beveridge)*

above the wooden deck and had rounded corners. The aft side of the coaming was fitted with a horizontal strengthening plate fixed externally and running the breadth of the structure.

No.3 Hatch ('Bunker Hatch')

The No.3 Hatch, also called the 'Bunker Hatch', was located in the forward Well deck between frames 92F and 88F; it measured 11ft 11in in length and 19ft 11in in breadth inside the coaming, and was constructed and covered for watertightness as described previously. The coaming stood 2ft 8in above the wooden deck and had rounded corners.

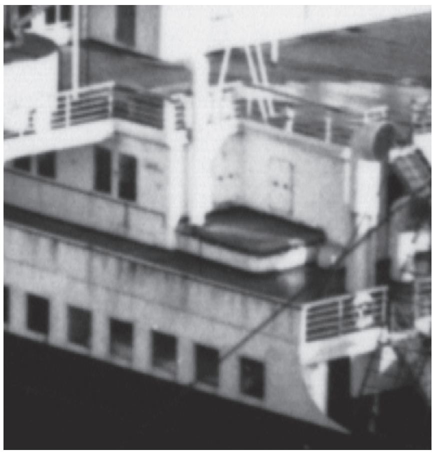


Fig. 9-27 **No.4 Hatch on *Olympic*** – In the center of this image can be seen the port-side No.4 Hatch on B Deck, as photographed on *Olympic* later in her career. With the exception of the large cowl ventilation head exiting the hatch at the outboard forward corner, the hatch coaming and cover remained otherwise unchanged from their 1911-12 appearance. The steel shutters seen covering the windows of the Second Class Smoke Room and Smoke Room Bar were original to the ship as well; these were installed when the hatch was being worked on to protect the windows from breakage.

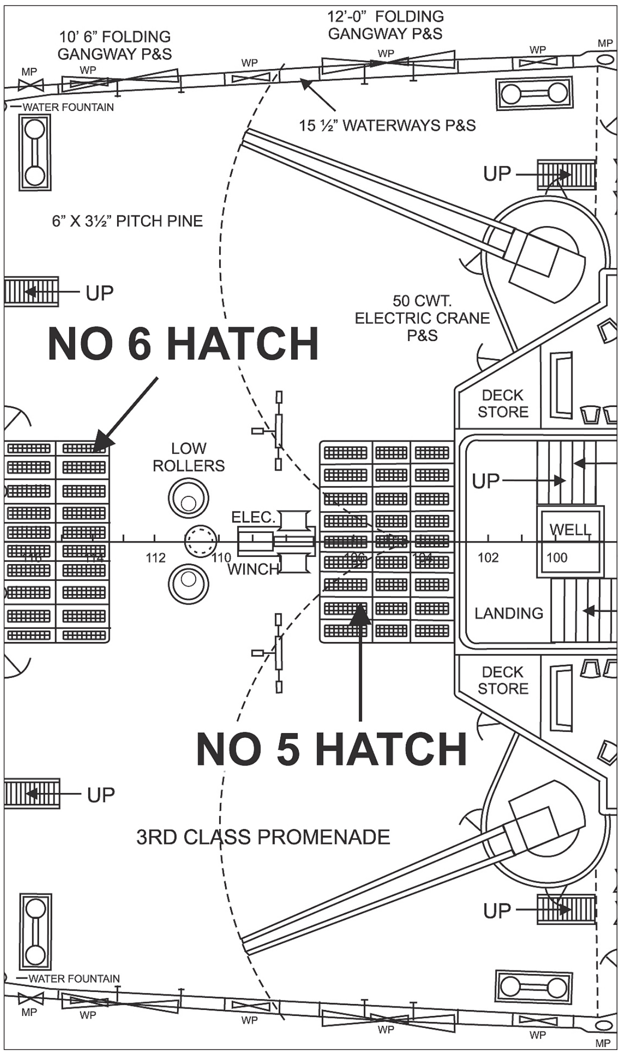

10' 6" FOLDING GANGWAY P&S
12'-0" FOLDING GANGWAY P&S
MP
WP
WATER FOUNTAIN
15 ½" WATERWAYS P&S
UP
6" X 3½" PITCH PINE
UP
50 CWT. ELECTRIC CRANE P&S
NO 6 HATCH
DECK STORE
LOW ROLLERS
ELEC.
WINCH
UP
WELL
112
110
102
100
LANDING
DECK STORE
NO 5 HATCH
UP
3RD CLASS PROMENADE
UP
WATER FOUNTAIN

Fig. 9-28 **Nos 5 and 6 Hatch Locations.** *(Illustration by Bruce Beveridge)*

NO.4 HATCH

Though there was one No.4 Hold, there were two hatches. These were positioned at the aft end of the B Deck between frames 90A and 93A port and starboard, with each hatch abutting the deckhouse bulkheads on two sides. The coamings around these hatches did not have the customary centerline peak, but instead were parallel to the camber of the deck, and were constructed and covered for watertightness as described previously. Each hatch measured 8ft 11in in length and 6ft 5½in in breadth inside the coamings. The coamings stood 2ft 5in above the wooden deck and were rounded at their after outboard corners.

NO.5 HATCH

The No.5 Hatch was located in the after Well Deck between frames 103A and 107A; it measured 11ft 11in in length and 18ft 0in in breadth inside the coaming, and was constructed and covered for watertightness as described previously. The coaming stood 2ft 8in above the wooden deck with rounded corners on the aft side only. The forward end of the coaming was formed by the aft bulkhead of the adjacent deckhouse.

NO.6 HATCH

The No.6 Hatch was located in the after Well Deck between frames 113½A and 117A, it measured 9ft 8in in length and 18ft 0in in breadth inside the coaming. The coaming stood 2ft 8in above the wooden deck and had rounded corners. The aft side of the coaming was formed by the forward exterior bulkhead enclosing the Third Class Entrance stairwell.

The No.1 Hatchway extended to the Lower Orlop Deck. The Nos 2 and 3 Hatchways extended down to the Orlop Deck, and the Nos 4, 5 and 6 Hatchways extended to G Deck. (It should be noted, though, that in speaking of a hatchway extending to a deck, a hatch was also located at the named deck, and therefore the deck below was also served by the hatch over that deck.)

The following tables provide a synopsis of the coaming heights and trunking at each deck for each of the hatchways:

Principle Specifications of Hatch Coamings

No.1 Hatch

Deck	Coaming height above steel (except as noted, and where trunked)	Comments
Forecastle	2ft 6in (above wood deck)	–
C	2ft 6in (above wood deck)	Trunked on after side
D	15in	Trunked on forward, P & S sides
E	8in bulb angle	Trunked on port side and forward port corner
F	15in	Trunked on forward, P & S sides
G	9in bulb angle	Trunked on forward, P & S sides
Orlop	8in bulb angle	–
Lower Orlop	8in bulb angle	–

No.2 Hatch

Deck	Coaming height above steel (except as noted, and where trunked)	Comments
C	2ft 8in (above wood deck)	–
D	15 ½in	–
E	8in bulb angle	Trunked on after and port sides, and on forward port corner
F	8in bulb angle	Trunked on after side by WTB
G	12in	Trunked on after side by WTB, and on P & S sides
Orlop	Flush with deck	–

No.3 (Bunker) Hatch

Deck	Coaming height above steel (except as noted, and where trunked)	Comments
C	2ft 8in (above wood deck)	–
D	15 ½in	–
E	13 ½in	–
F	8in bulb angle	Trunked on after side by Squash Racquet Court
G	–	Fully trunked
Orlop	–	Fully trunked

No.4 Hatches

Deck	Coaming height above steel (except as noted, and where trunked)	Comments
B	2ft 5in (above wood deck)	Trunked on forward and inboard sides
C	2ft 5in (above wood deck)	Trunked on forward and inboard sides
D	–	Fully trunked
E	8in bulb angle on outboard sides	Trunked on forward and after sides, and on inboard sides
F	–	Fully trunked
G	–	Fully trunked

No.5 Hatch

Deck	Coaming height above steel (except as noted, and where trunked)	Comments
C	2ft 8in (above wood deck)	Trunked on forward side by deckhouse
D	–	Fully trunked
E	12in on port side	Trunked on forward & after sides, and on starboard side
F	–	Fully trunked
G	8in bulb angle	–

No.6 Hatch

Deck	Coaming height above steel	Comments
C	2ft 8in (above wood deck)	Trunked on after side by deckhouse
D	–	Fully trunked
E	8in bulb angle	Trunked on forward & after sides
F	8in bulb angle	Trunked on forward & after sides
G	8in bulb angle	Trunked on forward & after sides

Chapter 10

Deckhouses and Expansion Joints

Steel deckhouses

The midship structures of the Boat, A and B Decks were all considered deckhouses. The structure on B Deck from the forward Well Deck to the after Well Deck was called the 'B Deckhouse;' the passenger accommodation on A Deck occupied the 'A Deckhouse'. This deckhouse enclosed the complete internal area surrounded by the promenade, but excluded the same. The Boat Deck contained deckhouses divided by open space. These deckhouses were framed and sheathed with steel, with the exception of specific areas where wood was required. The majority of the steel deckhouses were built before *Titanic* was launched from her construction berth. Some of the deckhouses on the Boat Deck, however, could not be erected until after the machinery was shipped. These deckhouses remained only partially completed until after the ship was moved to the Fitting-Out Wharf and the engines, boilers, and other machinery had been hoisted aboard and lowered into the ship. In addition, the wooden deckhouses were not constructed until the ship was at the Fitting-Out Wharf.

In constructing the deckhouses, vertical frames either of 6in channel section or 5in bulb-angle on A and B Decks, and 4in bulb angles on the Boat Deck, were riveted to the inboard sides of the deckhouse bulkheads. The bulb angle bars were joggled to allow the plates and straps of the bulkheads to lay directly on the frames, while liners were required for use with the channel bar frames. For longitudinal bulkheads, the frames were located generally on the same 3ft centers as were the main frames and deck beams amidships, while various spacings were used for the frames of the transverse bulkheads, with the closest spacing being found in the bulkheads forming the forward end deckhouses on A and B Decks. Additional strengthening of these forward bulkheads was achieved through the installation of several deep web frames. In all cases the spacing of frames was adjusted as required to suit the placement of the doors, windows and other architectural features of the rooms the deckhouses enclosed. In most locations, the frames of the deckhouse bulkheads were attached to the deck through half-diamond gusset plates and angle bar lugs, except for the frames of the deckhouse sides ahead of the forward First Class Entrance on A Deck, where knee brackets and lugs were employed. When the location of the longitudinal framing coincided with the position of the deck beams, the tops of the frames were attached to the beams through knee brackets. The tops of the transversely disposed frames were connected to the underside of the deck above through knee brackets and angle bar lugs, as were longitudinal frames where shifted away from the location of deck beams.

A continuous horizontal strap was fitted to support the steel plating at the middle level of the bulkhead. This would also act as a spacer for the plates described below. Externally, the deck beams were attached to the bulkheads through castings called 'collars' riveted to the bulkheads externally and caulked watertight.

The exterior surfaces of the deckhouses were constructed of thin steel plates which were joined primarily using flush seams and landings, giving these bulkheads their smooth appearance.

The deckhouse bulkheads on A and B Decks were constructed using two slightly different methods of plating. The plating of most of these bulkheads consisted of three horizontal sections. The base was formed by a coaming plate which generally had an exposed height of 18in to the lowest landing of bulkhead plating, except with the bulkheads in the vicinity of the Verandah Café and Palm Courts, where this was reduced 15in in order to clear the bottoms of the low window sills. The coaming plate was attached to the deck by a continuous angle foundation bar. At the top of the longitudinal bulkheads, a corresponding frieze plate, also of varying widths, was fitted. The frieze plate was notched along the top edge both to clear the deck beams and to fill the open space between; it was attached to the underside of the deck above through single angle bars fitted intercostally between the deck beams. Where additional strength was required in way of some of the large window openings, instead of fitting separate doublings, the width of the frieze

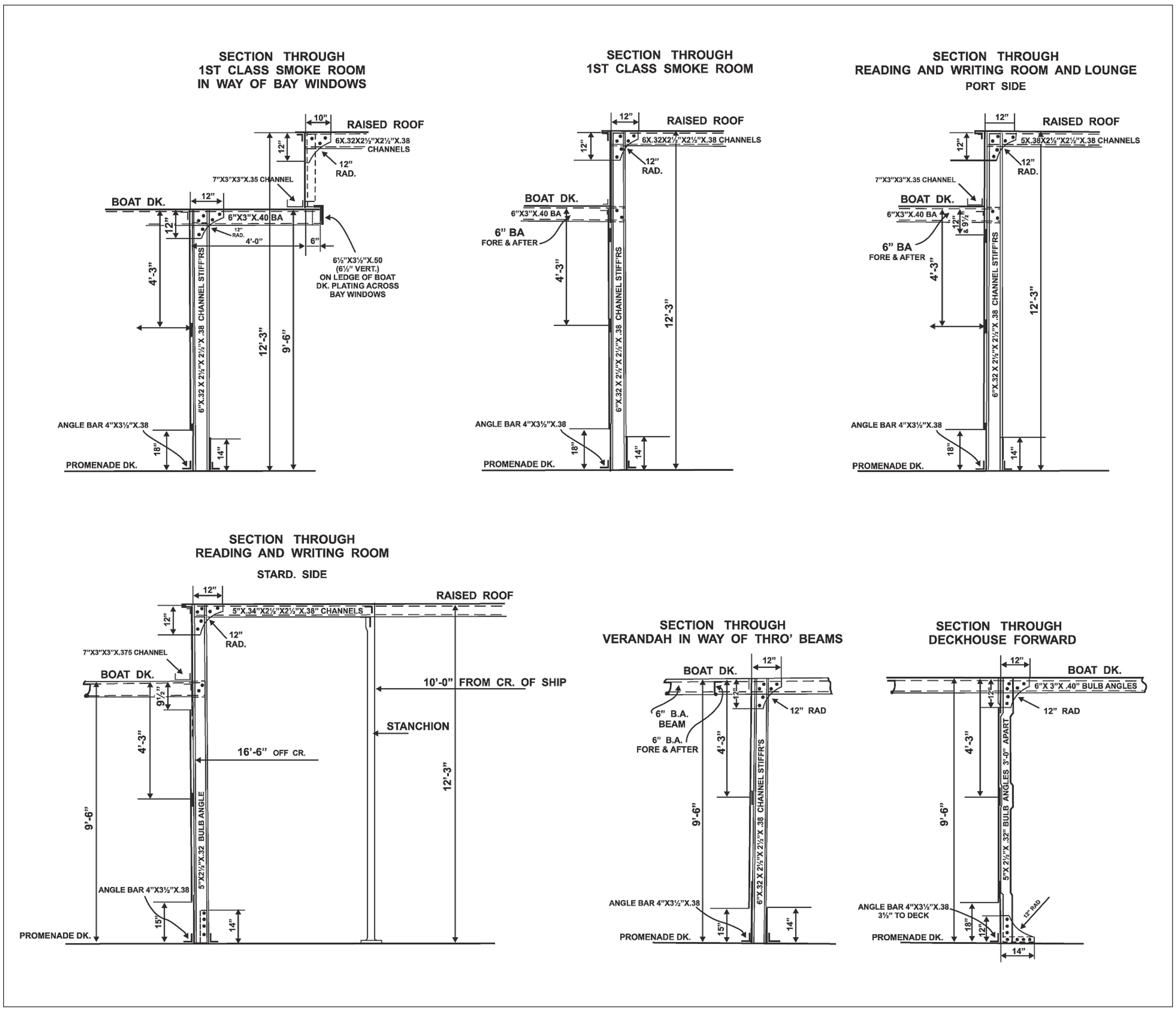

SECTION THROUGH 1ST CLASS SMOKE ROOM IN WAY OF BAY WINDOWS
RAISED ROOF
10"
12"
6X.32X2½"X2½"X.38 CHANNELS
12" RAD.
7"X3"X3"X.35 CHANNEL
BOAT DK.
6"X3"X.40 BA
4'-0"
6"
6½"X3½"X.50 (6½" VERT.) ON LEDGE OF BOAT DK. PLATING ACROSS BAY WINDOWS
4'-3"
12'-3"
9'-6"
6"X.32 X 2½"X 2½"X .38 CHANNEL STIFF'RS
ANGLE BAR 4"X3½"X.38
18"
14"
PROMENADE DK.
SECTION THROUGH 1ST CLASS SMOKE ROOM
6X.32X2½"X2½"X.38 CHANNELS
6" BA FORE & AFTER
SECTION THROUGH READING AND WRITING ROOM AND LOUNGE PORT SIDE
7"X3"X3"X.35 CHANNEL
9½"
SECTION THROUGH READING AND WRITING ROOM STARD. SIDE
5"X.34"X2½"X2½"X.38" CHANNELS
7"X3"X3"X.375 CHANNEL
10'-0" FROM CR. OF SHIP
STANCHION
16'-6" OFF CR.
5"X2½"X.32 BULB ANGLE
15"
SECTION THROUGH VERANDAH IN WAY OF THRO' BEAMS
6" B.A. BEAM
6" B.A. FORE & AFTER
12" RAD
6"X.32 X 2½"X 2½"X .38 CHANNEL STIFFR'S
SECTION THROUGH DECKHOUSE FORWARD
6"X 3"X .40" BULB ANGLES
5"X 2½"X .32" BULB ANGLES 3'-0" APART
ANGLE BAR 4"X3½"X.38 3½" TO DECK
12" RAD

Fig. 10-1 **Sections Through Various Deckhouses**. *(Illustration by Bruce Beveridge based on original H&W Promenade Deckhouse plan)*

plate was increased behind the exterior plates, where it was brought down past the corners of the windows. Both the coaming and frieze plates were lapped and double-riveted.

With most of the deckhouse bulkheads, the space between the coaming and frieze plates was filled by two horizontal strakes of steel plate. The strakes were edge-butted, with the horizontal seam being joined through a continuous butt strap which ran between the plates and frames at the mid level of the bulkhead. The vertical seams of these strakes were also end butted and single- or double-riveted through straps fitted on the interior side of the bulkhead. The top and bottom landings of central plate strakes overlapped the frieze and coaming plates, to which they were riveted. Both single and double flush riveting was used in connecting the bulkhead plates to one another and to the coaming and frieze plates. The transverse bulkheads were built in much the same way, but did not utilize the frieze plate, the top strake of the central plating being instead extended the full height to

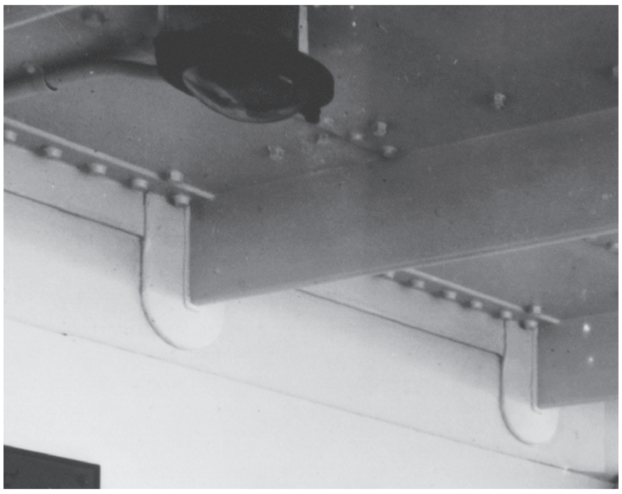


Fig. 10-2 **Beam Collars** – Beam collars fitted against a deckhouse frieze plate on *Olympic*. A 'collar' was a fitting installed on a vertical surface such as a bulkhead, to create a weather- or watertight seal around horizontal structural members. Like the horizontal shoes illustrated in Chapter 8 of this volume, these castings could be made from either steel or iron.

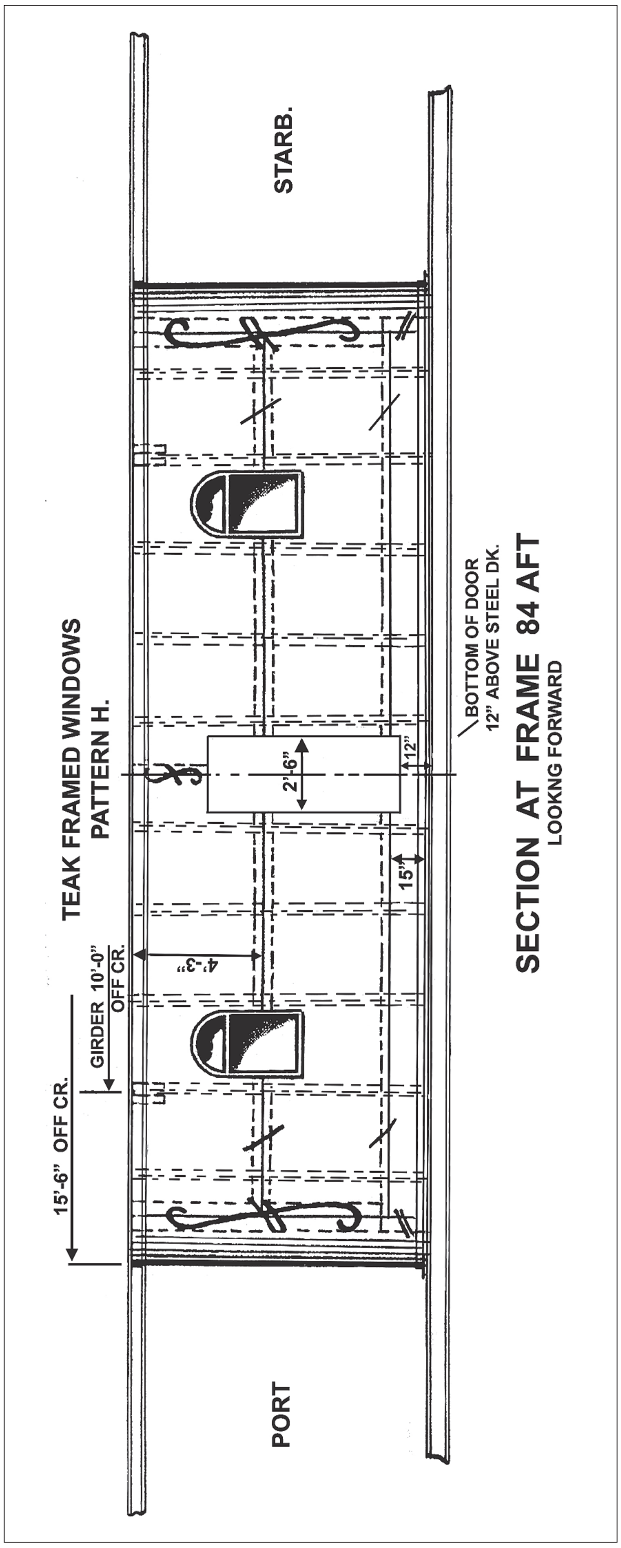


Fig. 10-3 **Deckhouse Bulkhead at After End of A Deck** – A drawing showing the structural details of the bulkhead which formed the after wall of the Fan Room at the after end of A Deck. Even in a small drawing such as this there are numerous details of interest. In addition to the obvious door and window openings, the internally located frames, stiffeners, the overlapped edges of lapped seams and butt straps behind the flush seams are indicated by dashed lines. Diagonal hashed lines indicated the number of rows of rivets to be employed in each lap, or to either side of each flush seam, while the flush seams are indicated by the elongated 'S' symbol drawn symmetrically about the seam line. *(Illustration by Bruce Beveridge based on original H&W Promenade Deckhouse plan)*

the deck head. The corners of the bulkheads were formed from steel plate rolled to a 12in radius, and double-riveted through butt straps to the sides and ends of the deckhouses. The thickness of the plating and coamings was increased at the ends of the deckhouse where exposure to the elements and stress was the greatest. When possible, openings such as doors and windows were cut out of the plates before installation.

The bulkheads of the A Deckhouse were constructed in much the same as those on the deck beneath, except in the areas containing the large windows that extended along with the raised roof to the Boat Deck above. In those cases, the frieze plate was replaced by a third strake of plating. In the case of the First Class Smoke Room, the bottom edge of the added strake was placed behind, and riveted to, the upper landing of the second strake, while in the case of the First Class Lounge and the First Class Reading and Writing Rooms, the additional strake was edge-butted to the one below through a second continuous horizontal strap.

The steel deckhouses on the Boat Deck were framed and plated in essentially the same manner at the single-story deckhouse on A and B Decks, with the exception of the frieze plates, as these were unnecessary on deckhouses standing in the open. Instead, with these deckhouses, the top strakes of the bulkheads terminated at the full height of the deckhouse. In the case of deckhouses on which the roofs were sheathed in wood planks, a continuous angle bar was riveted around the periphery of the deckhouse at the outer top edges of the bulkheads. The steel plates of the deckhouse roof overlapped and were riveted to the horizontal flange of the angle. The teak margins of the wood sheathing, the outboard edges of which were milled into a beaded or bull-nose profile, overlapped the underlying steel by several inches. The edges of the deckhouse bulkheads of the raised roofs were finished in a similar manner. On deckhouses not sheathed by wood decks, the bulkhead tops were raised slightly above the steel plates of the roof, creating a rim. Within the rim, a continuous angle bar fitted around the inner periphery joined the edges of the roof plates to the inside of the bulkhead plates, while half-round or semi-elliptical section steel cope was riveted around the top outside edges, both to add stiffness and to lend a more finished appearance to the work.

After the rivet-work and caulking of the deckhouse bulkhead plates had been completed, the flush seams were filled up with a thick, putty-like 'stopping' – a composition made from stiff white-lead paint and red-lead powder. A second coat was applied in a wide swath over and to either side of the joints. Once dry, the filled joints were wet-rubbed with pumice stones, and then a final coat of lead primer was applied, resulting in the smooth, finished appearance so readily apparent in photographs of these areas of the ship.

In areas where there was a possibility that connected joints might creak due to the working of the structure, an application of single-ply flannel was inserted between structural members. The joints at the corners of the deckhouses, and the connections around web frames and in way of the expansion joints were all flannelled, and particular attention was paid in this regard to the structural connections in way of the passenger staterooms.

Expansion joints

The expansion joints of *Titanic* can be likened to the expansion joints used in large highway and motorway bridges today. Though different in construction, they serve the same purpose – to compensate for shifting of the connecting structures when under straining forces.[1]

Titanic was fitted with two expansion joints, one at frame 49F and one at frame 28A. As stated previously, the decks comprising the superstructure were not designed to be integral to the structure of the hull, B Deck being the uppermost portion of the hull girder. The expansion joints started within the deckhouse bulkheads immediately above the B Deck level and effectively subdivided the superstructure into three separate entities.

On the wood-sheathed deck surfaces, the ends of the steel deck plates immediately forward and aft of the joints were reinforced with 2½in x 2½in angle boundary bars against which the margin planks of the wood deck or roof abutted. The interior steel deck plates were reinforced at the edges of the joints in a similar manner, except that the vertical flanges bounding the joints inside the deckhouses were planed down to the height of the surrounding Litosilo. In the expansion joint recesses, where one of the two steel bulkheads forming the recess was located immediately adjacent to the joint, a length of channel bar was used instead of angle, with the flange opposite the joint being used as the foundation bar of the adjacent bulkhead. The open gap between the edges of each joint was set at approximately 2in. The opening of the gap in the exterior decking was covered with an 8in grooved brass plate screwed to the deck along its forward edge, but left unattached on the opposite side.

The exception to this was where the expansion joint recess was formed within the deckhouses. In these cases, there was no brass plate. However, in the spaces where the expansion joints crossed stateroom passageways, a plate was provided, fastened to the deck this time only along the aft edge of the plate.

On the Boat and A Decks, beneath each of the expansion joints a leather strip having a thickness of ⅜in and covering an area of 9in wide was mounted to the underside of the deck. Each of these leather strips was held firmly in place beneath along the forward and after edges of the joint it covered by 1¼in x ⅜in galvanized-iron strips running the entire length of the joint, fastened at 4in intervals with 5⁄16in-diameter

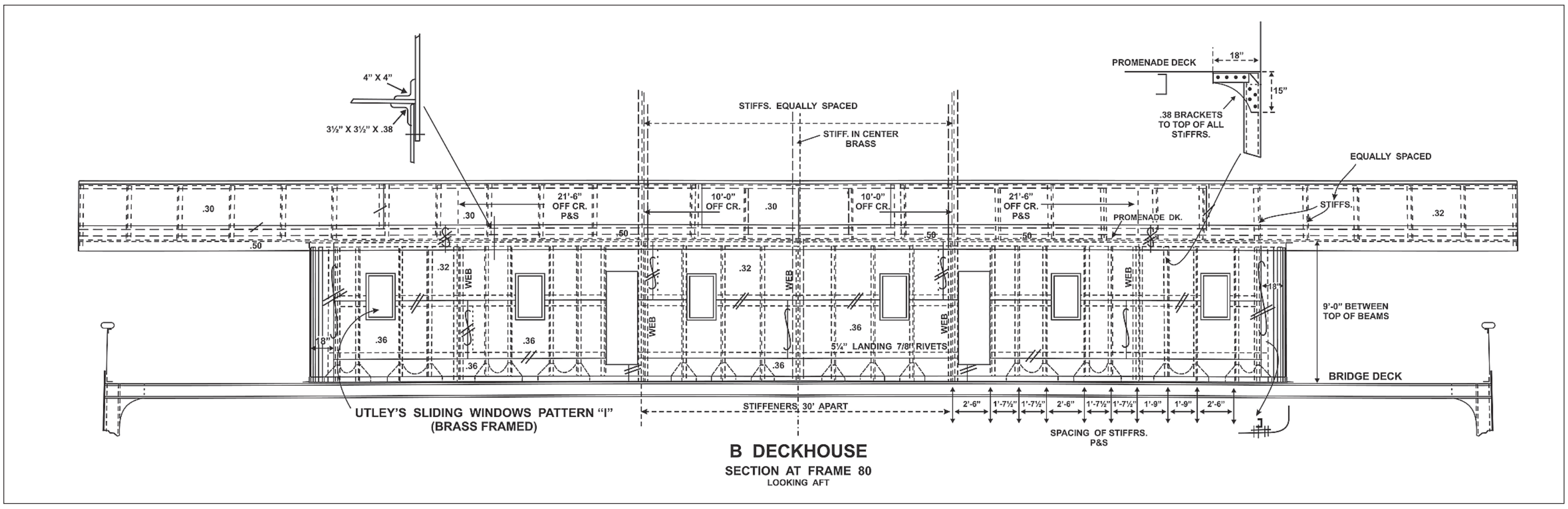


Fig. 10-4 **Forward Bulkhead – B Deck** – This drawing is based upon the elevation for this bulkhead from the original 400-01 B Deckhouse plans, and has been altered to include the two doors which were added to *Titanic* to provide access passage between the forward B Deck promenade and the corridors of the First Class accommodations. While the original drawing was not altered to detail the various structural changes to *Titanic*'s B Deckhouse, there are numerous small free-hand sketches and notes penciled in among the careful linework of the draftsman. These additional notes and sketches specified what original windows and doors would be retained or removed, where new ones would be added, and where existing steelwork would be removed to make way for the additional First Class staterooms. *(Illustration by Bruce Beveridge based on original H&W Bridge Deckhouse plan)*

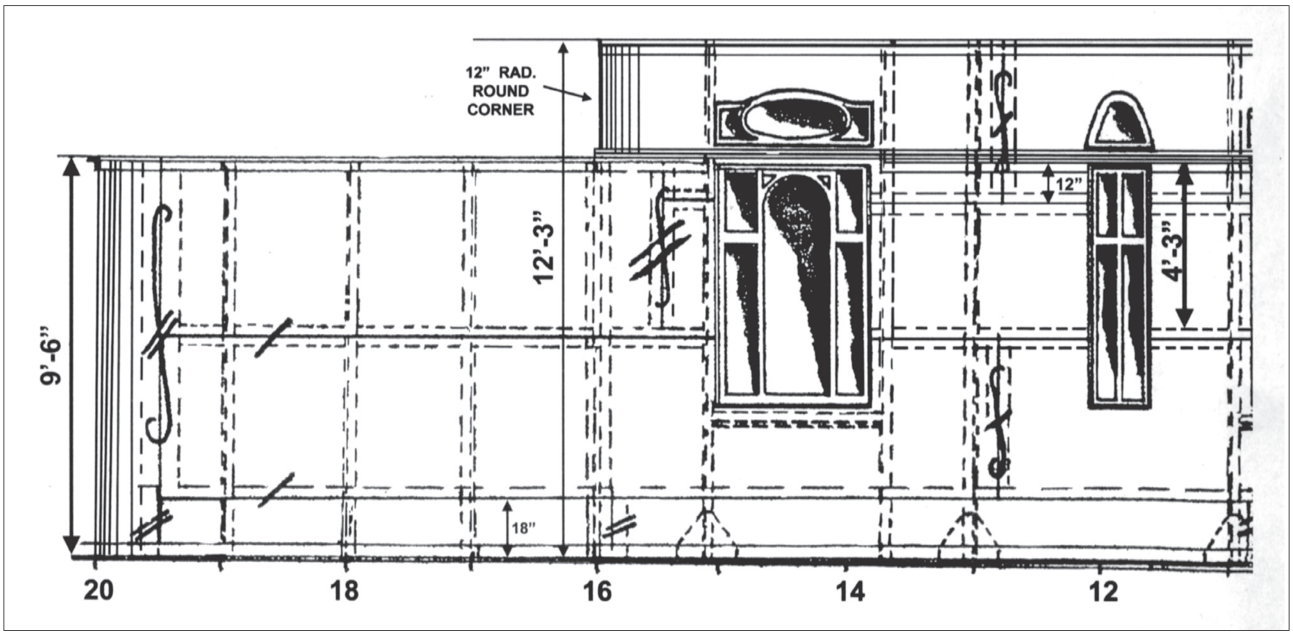


Fig. 10-5 **Lounge Deckhouse Elevation – Partial** – A portion of a deckhouse bulkhead elevation along A Deck, in way of the after starboard corner of the First Class Lounge. This detail shows the transition from the usual two strakes of horizontal plates to the three necessary to extend the bulkhead to the increased height of the raised roof. (If one counts the coaming at the bottom, there are actually four strakes.) The dashed triangular shapes at the bottoms of the frames represent the half-diamond gussets which tied many of the bulkhead frames to the deck plates. Gussets of this type were used in areas where additional resistance against shifting required both athwartship and longitudinal bulkheads. *(Illustration by Bruce Beveridge based on original H&W Promenade Deckhouse plan)*

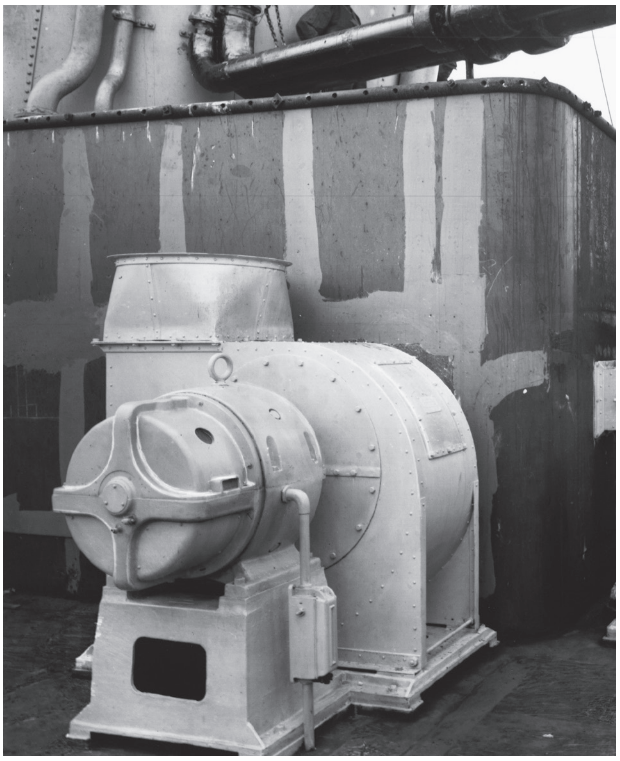


Fig. 10-6 **Preparation of Deckhouse Plate Seams** – The seams and rivet points in the plating were filled and covered over with 'stopping' – a thickened, lead-paint composition – which was then smoothed with a pumice stone before painting to provide a seamless finish. *(H&W/Authors' collection)*

screws. The leather strip was made to be somewhat wider than the area it actually covered, creating a downward bulge measuring 1½in deep from the top surface of the leather to the underside of the deck. The purpose of the bulge was to allow the excess leather to move in bellows-fashion with the opening and closing of the gap, thus maintaining a watertight seal. The downward bulge served the additional purpose of forming a gutter. Any water which collected in these flexible gutters was directed outboard to the edges of the decks and deckhouse roofs, where it drained into galvanized iron cups connected to scupper pipes, eventually flowing overboard through scupper openings at the level of B Deck.

Where they passed through the vertical bulkheads and bulwarks, the manner in which the expansion joints were covered differed from that of the decks mainly in that no brass covering plates were used. Instead, these surfaces were sealed by the leather strips alone. The vertical gaps through deckhouse bulkheads were covered by a leather strip fitted to the exterior surface of the bulkhead with the bulged surface protruding outward. Where the expansion joints subdivided the vertical bulwarks at the edges of the decks, a leather strip was attached on both the inside and outside of the plating with the bulge of the inside strip protruding inboard and that of the outside strip protruding outboard. These joints were covered on both sides as a safety precaution to prevent

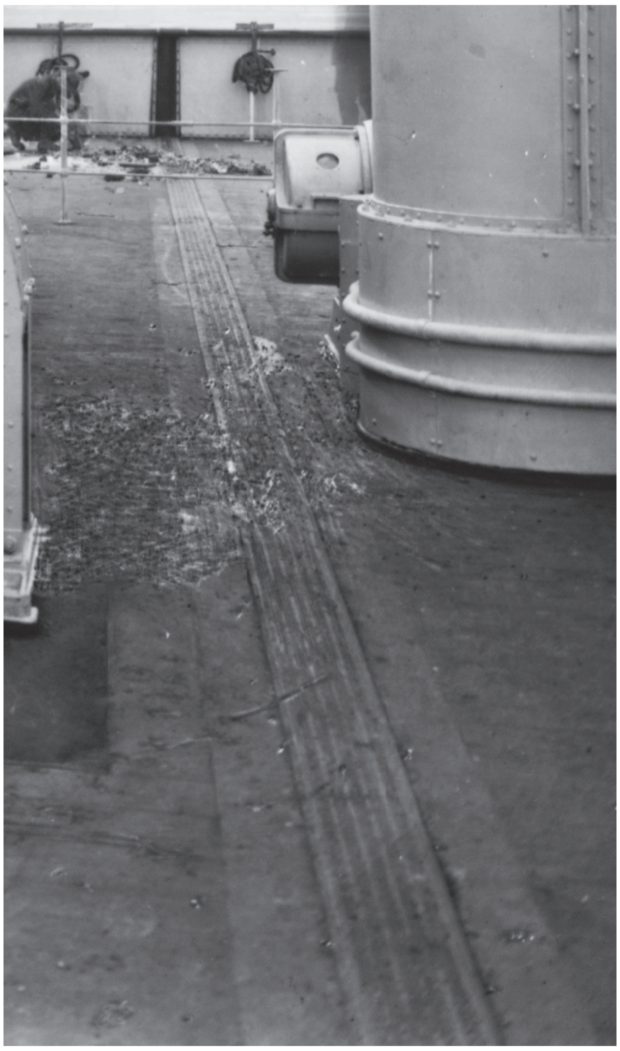


Fig. 10-7 **Expansion Joint on Boat Deck** – The after expansion joint on *Olympic*'s Boat Deck, photographed during construction. The brass covering plate is plainly visible. *(H&W/Authors' collection)*

people's limbs from becoming caught between the two bulwarks sections as they worked with the flexing of the vessel. For the same reason, where teak rails were divided by expansion joints, leather sleeves were installed over the gaps.

Wheelhouse and Navigating Bridge shelter[2]

The Wheelhouse and the Navigating Bridge shelter were unique because, unlike all of the other deckhouses on the ship, these structures were built entirely of wood.

Wood construction was most suitable in the vicinity of the compasses as steel had a magnetic attraction on the needle; hence, it was general practice to avoid placing any steelwork within a 10ft radius of the compass. All metal fittings and fasteners were of brass or bronze due to their non-magnetic properties.

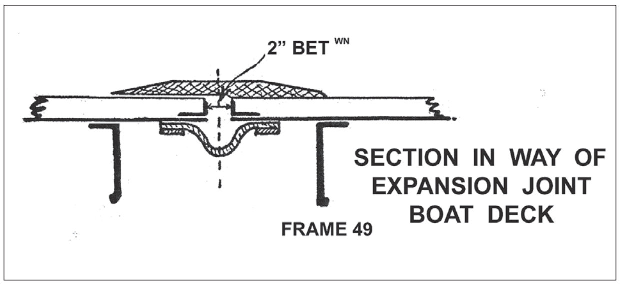


Fig. 10-8 **Section Through Expansion Joint on Boat Deck** – A section through the forward expansion joint on the Boat Deck at frame 49F; the after expansion joint at frame 28A was constructed in the same manner. *(Illustration by Bruce Beveridge based on original H&W Boat Deck Iron plan)*

The Wheelhouse and the Navigating Bridge shelter were made of heavy timber frameworks with lighter secondary framing to fill in the spaces. The primary framing was composed of stout wooden coaming pieces which were bolted to the steel deck. Vertical 'standards' were stepped upon the coamings at regular intervals.[3] The standards were fastened into the coamings on the deck, and to the header above through mortise-and-tenon joints, and were tied to one another through horizontal stringers fitted between them.

The spaces between the standards were filled with light framing which provided the necessary points for securely attaching the interior lining and exterior sheathing.

It was common shipbuilding practice to construct wooden deckhouses in the Joiners' Shop first. When finished, the individual parts were marked as to their location, after which they were disassembled and then re-erected in position aboard ship. During re-assembly on the ship, the coamings were first bolted directly to the steel; the deck planks were then fitted and caulked around them. It was essential that the coaming was well fixed to the deck due to the heavy weather and high winds these houses had to withstand. As with the steel deckhouses, a teakwood margin was fitted around the outer periphery, against which the yellow pine decking butted.

After the framework of the houses had been erected, the covering or roof was fixed in place. The roof framing was laid with yellow pine tongue-and-groove planks having a width of approximately 4in. The planks were fastened to the framework with large brass bolts, the heads of which were sunk below the surface and plugged. The wooden planking of the roof was then sealed externally with a bituminous paint solution. Lastly, the roof was covered with canvas ducking which was then sealed with a few coats of medium-gray enamel.

While the Navigating Bridge shelter and the Wheelhouse were primarily made of teak, pine was

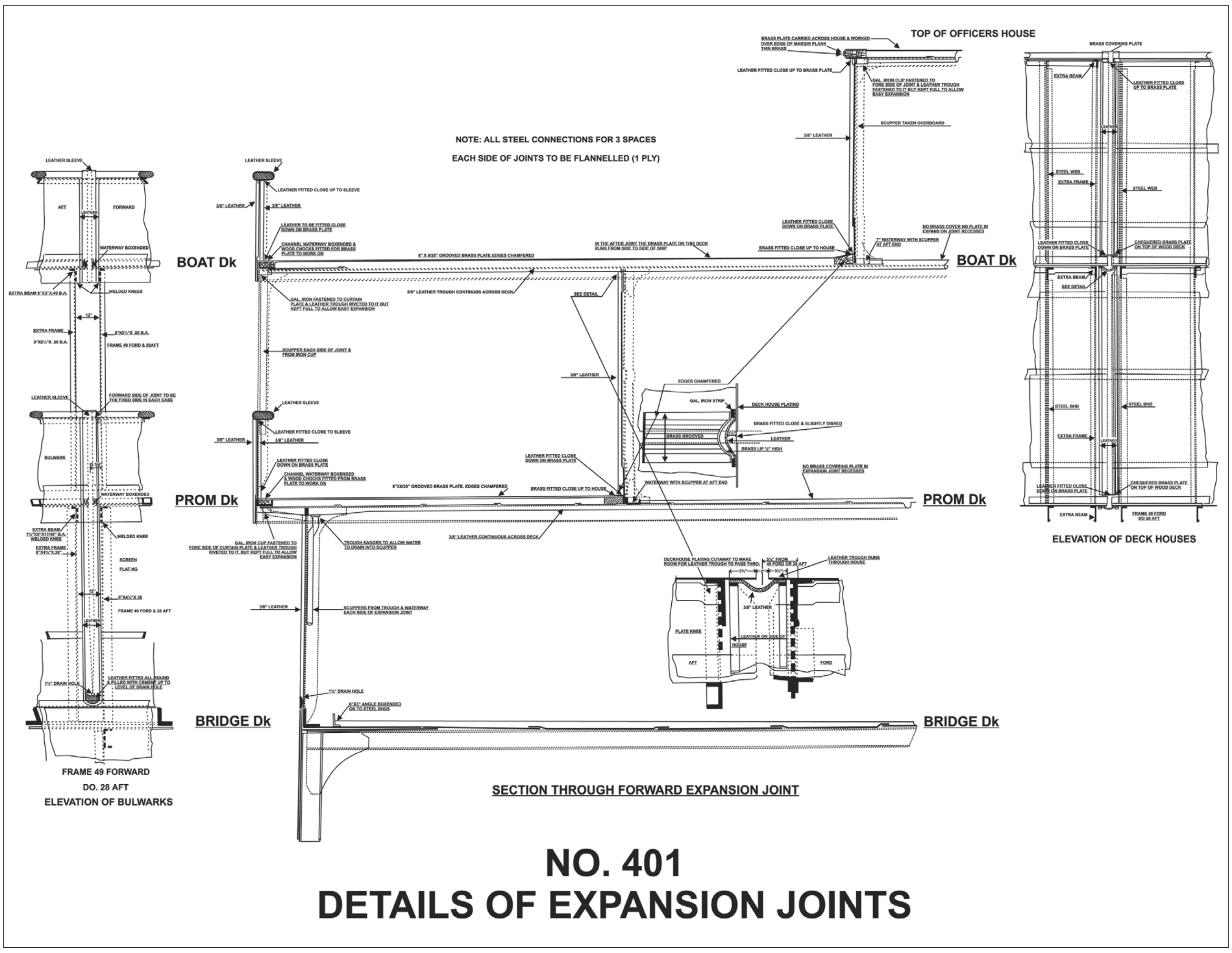

TOP OF OFFICERS HOUSE
NOTE: ALL STEEL CONNECTIONS FOR 3 SPACES
EACH SIDE OF JOINTS TO BE FLANNELLED (1 PLY)
BOAT Dk
BOAT Dk
PROM Dk
PROM Dk
BRIDGE Dk
BRIDGE Dk
FRAME 49 FORWARD
DO. 28 AFT
ELEVATION OF BULWARKS
SECTION THROUGH FORWARD EXPANSION JOINT
ELEVATION OF DECK HOUSES
NO. 401
DETAILS OF EXPANSION JOINTS

Fig. 10-9 **Expansion Joints – Longitudinal Half Section and Elevations.** *(Illustration by Bruce Beveridge based on original H&W Expansion Joint plan)*

used on surfaces not directly exposed to the weather. The exteriors surfaces were first sheathed in a layer of tongue-and-groove boards, which were then sealed smooth with a finishing layer of teakwood paneling; the interiors were lined with vertical tongue-and-groove yellow pine, with a half-runner fitted to cover the joint between the roof and bulkheads. After completion, the bulkheads and ceiling were finished off in white enamel paint.

In addition to the Wheelhouse and Navigating Bridge shelter, there were a number of steel deckhouses on *Titanic*'s Boat Deck that had tongue-and-groove roofs. Among these were the Officers' Mess to starboard of the No.3 Funnel, the after half of the roof of the No.4 Funnel deckhouse, the roof over the elevator machinery house on top of the Second Class Entrance, and the Bridge wing cabs. To ensure the waterproof integrity of these structures several forms of standard coverings were used. The 1½in tongue-and-groove yellow pine used for the roofs over the Bridge wing cabs and the roof of the Officers' Mess was covered with a waterproofed board called a 'covering board'. This process consisted of a wooden veneer, usually of teak, that covered the entire roof. In the case of the Officers' Mess roof, where the edges of the covering boards abutted a margin piece or the top edges of the deckhouse bulkheads, they were sealed with cement. The roof over the Second Class elevator machinery house was also covered with tongue-and-groove planking, sealed either with a covering board or ducking. The coverings of the structures mentioned above were painted with medium gray enamel.

The Navigating Bridge shelter was afforded good visibility both forward and to the sides through eleven rectangular plate glass windows. The nine forward-facing windows were framed in teak and designed to slide vertically.[4] To protect those standing watch in heavy weather, the forward-facing windows were equipped with vertical-sliding storm shutters fitted internally within tracks; each shutter had a round opening or 'port glass' in the middle to provide limited visibility. The two side windows – also framed in teak – opened outboard, pivoting on vertical hinges affixed to the forward sides of their frames.

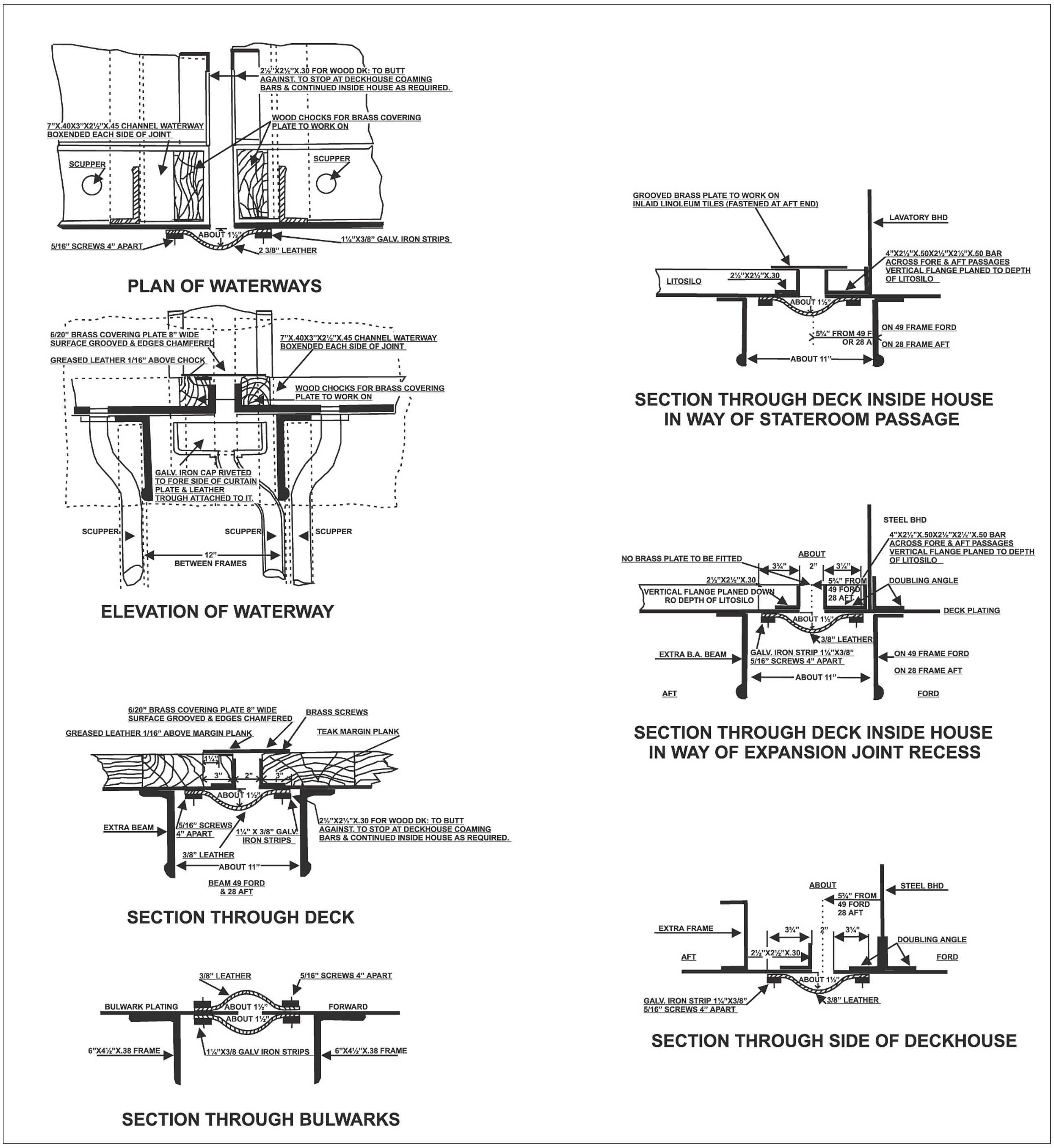

2½"X2½"X.30 FOR WOOD DK: TO BUTT AGAINST. TO STOP AT DECKHOUSE COAMING BARS & CONTINUED INSIDE HOUSE AS REQUIRED.
7"X.40X3"X2½"X.45 CHANNEL WATERWAY BOXENDED EACH SIDE OF JOINT
WOOD CHOCKS FOR BRASS COVERING PLATE TO WORK ON
SCUPPER
SCUPPER
ABOUT 1½"
5/16" SCREWS 4" APART
1¼"X3/8" GALV. IRON STRIPS
2 3/8" LEATHER
PLAN OF WATERWAYS
6/20" BRASS COVERING PLATE 8" WIDE SURFACE GROOVED & EDGES CHAMFERED
7"X.40X3"X2½"X.45 CHANNEL WATERWAY BOXENDED EACH SIDE OF JOINT
GREASED LEATHER 1/16" ABOVE CHOCK
WOOD CHOCKS FOR BRASS COVERING PLATE TO WORK ON
GALV. IRON CAP RIVETED TO FORE SIDE OF CURTAIN PLATE & LEATHER TROUGH ATTACHED TO IT.
SCUPPER
SCUPPER
SCUPPER
12" BETWEEN FRAMES
ELEVATION OF WATERWAY
6/20" BRASS COVERING PLATE 8" WIDE SURFACE GROOVED & EDGES CHAMFERED
BRASS SCREWS
GREASED LEATHER 1/16" ABOVE MARGIN PLANK
TEAK MARGIN PLANK
1¼"
3"
2"
3"
ABOUT 1½"
EXTRA BEAM
5/16" SCREWS 4" APART
1¼" X 3/8" GALV. IRON STRIPS
2½"X2½"X.30 FOR WOOD DK: TO BUTT AGAINST. TO STOP AT DECKHOUSE COAMING BARS & CONTINUED INSIDE HOUSE AS REQUIRED.
3/8" LEATHER
ABOUT 11"
BEAM 49 FORD & 28 AFT
SECTION THROUGH DECK
3/8" LEATHER
5/16" SCREWS 4" APART
BULWARK PLATING
ABOUT 1½"
ABOUT 1½"
FORWARD
6"X4½"X.38 FRAME
1¼"X3/8 GALV IRON STRIPS
6"X4½"X.38 FRAME
SECTION THROUGH BULWARKS
GROOVED BRASS PLATE TO WORK ON INLAID LINOLEUM TILES (FASTENED AT AFT END)
LAVATORY BHD
4"X2½"X.50X2½"X2½"X.50 BAR ACROSS FORE & AFT PASSAGES VERTICAL FLANGE PLANED TO DEPTH OF LITOSILO
LITOSILO
2½"X2½"X.30
ABOUT 1½"
5¾" FROM 49 F OR 28 A
ON 49 FRAME FORD
ON 28 FRAME AFT
ABOUT 11"
SECTION THROUGH DECK INSIDE HOUSE IN WAY OF STATEROOM PASSAGE
STEEL BHD
4"X2½"X.50X2½"X2½"X.50 BAR ACROSS FORE & AFT PASSAGES VERTICAL FLANGE PLANED TO DEPTH OF LITOSILO
NO BRASS PLATE TO BE FITTED
ABOUT
3¾"
2"
3¼"
2½"X2½"X.30
5¾" FROM 49 FORD 28 AFT
DOUBLING ANGLE
VERTICAL FLANGE PLANED DOWN RO DEPTH OF LITOSILO
DECK PLATING
ABOUT 1½"
3/8" LEATHER
EXTRA B.A. BEAM
GALV. IRON STRIP 1¼"X3/8" 5/16" SCREWS 4" APART
ON 49 FRAME FORD
ON 28 FRAME AFT
ABOUT 11"
AFT
FORD
SECTION THROUGH DECK INSIDE HOUSE IN WAY OF EXPANSION JOINT RECESS
ABOUT
STEEL BHD
5¾" FROM 49 FORD 28 AFT
EXTRA FRAME
3¾"
2"
3¼"
DOUBLING ANGLE
AFT
2½"X2½"X.30
FORD
ABOUT 1½"
GALV. IRON STRIP 1¼"X3/8" 5/16" SCREWS 4" APART
3/8" LEATHER
SECTION THROUGH SIDE OF DECKHOUSE

Fig. 10-10 **Expansion Joints – Various Sectional Details.** *(Illustration by Bruce Beveridge based on original H&W Expansion Joint plan)*

The Navigating Bridge shelter was open on both sides to allow free passage to the officers while crossing from side to side. However, portable teak boards were provided to further close in the shelter in severe weather; these were shipped by attaching them to the deck via sockets and to the roof header with slip bolts.

The arrangement of windows fitted in the Wheelhouse structure was similar to that of the Navigating Bridge shelter, but with five forward-facing and two side windows. These windows were provided with internal shutters that prevented any possible light from inside the Wheelhouse, or from the doorways into the deckhouse immediately aft, from interfering with the night vision of those standing watch just outside.

Two doors, minus the common round windows, were arranged to open outward onto the deck from the Wheelhouse – one port and one starboard. Cabin hooks were fitted to hold them against the deckhouse when open.

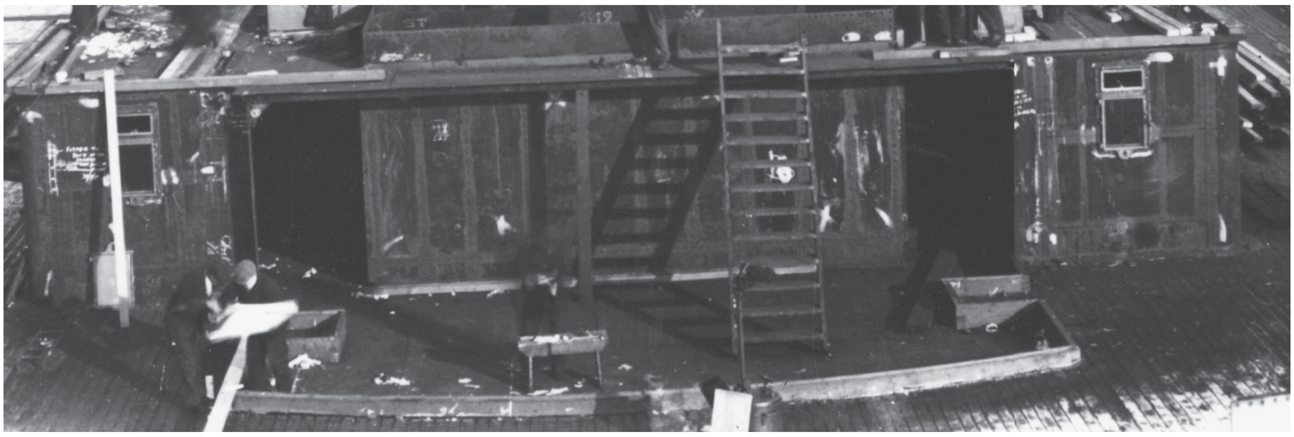


Fig. 10-11 ***Olympic*'s Wheelhouse Under Construction** – The rounded coaming of *Olympic*'s original Wheelhouse is in place in this January 1911 photograph taken during fitting out. *Titanic* was given a somewhat narrower and shorter Wheelhouse with a straight forward bulkhead, but aside from these differences, the method of construction was the same. *(H&W/Authors' collection)*

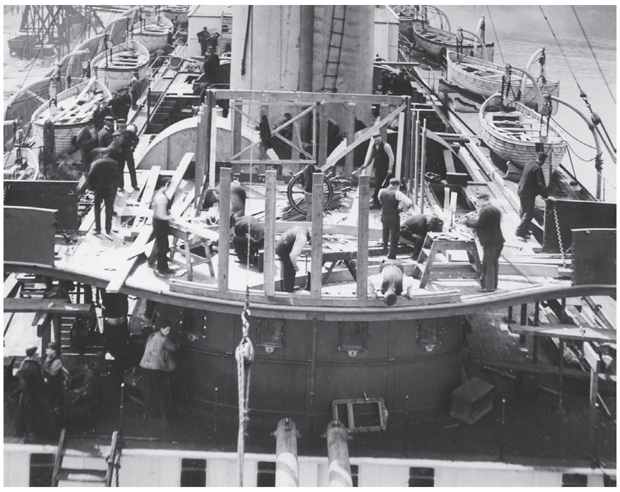


Fig. 10-12 **Bridge and Wheel House on *Oceanic*** – The Navigating Bridge and Wheelhouse of the *Oceanic* in the course of construction, June 1899. *(H&W/Authors' collection)*

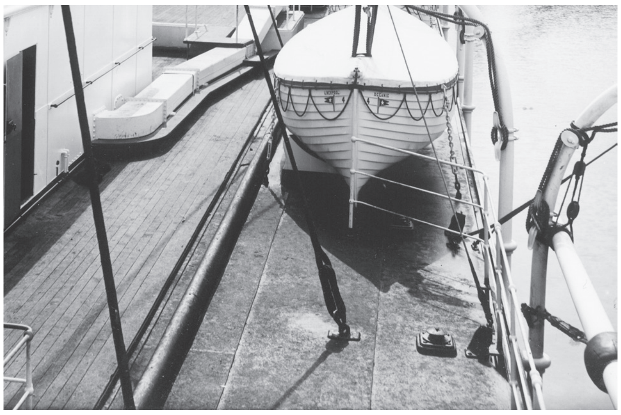


Fig. 10-14 **Canvas Deck Waterproofing on *Oceanic*, 1899** – The canvas waterproofing seen covering the wood deck laid above the *Oceanic*'s open, but shaded, promenades was much the same as what would have been used to cover the roof over *Titanic*'s Navigating Bridge and Wheelhouse. Note that further inboard, where the deck is immediately above enclosed accommodation space, per Board of Trade regulations the surface of the Boat Deck has changed from canvas-covered wood to wood-sheathed steel plate. *(H&W/Authors' collection)*

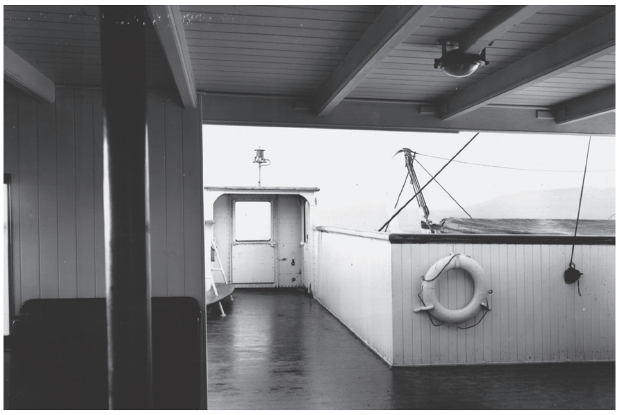


Fig. 10-13 **Interior of Navigating Bridge on *Olympic*** – In this image from *Olympic*, the tongue-and-groove sheathing is evident beneath the waterproof covering of the roof over the Navigating Bridge and Wheelhouse. *(H&W/Authors' collection)*

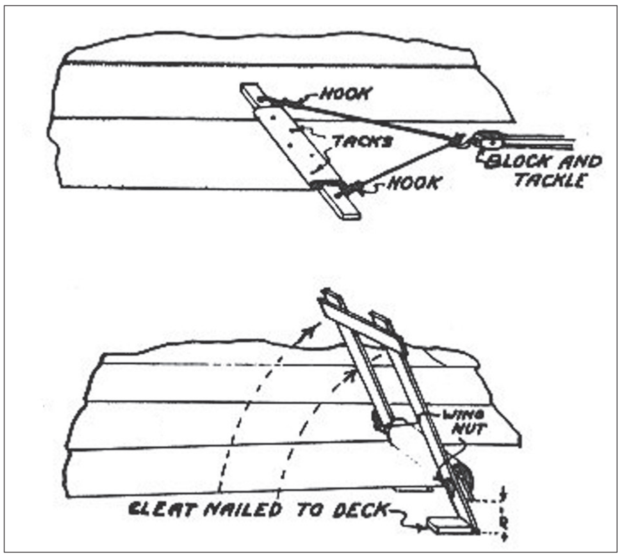


Fig. 10-15 **Methods of Laying Canvas Ducking** – Two methods of stretching canvas ducking for roof and deck coverings. This form of waterproofing for deckhouse roofs and light decks was common in *Titanic*'s era, and was used quite extensively aboard merchant vessels.

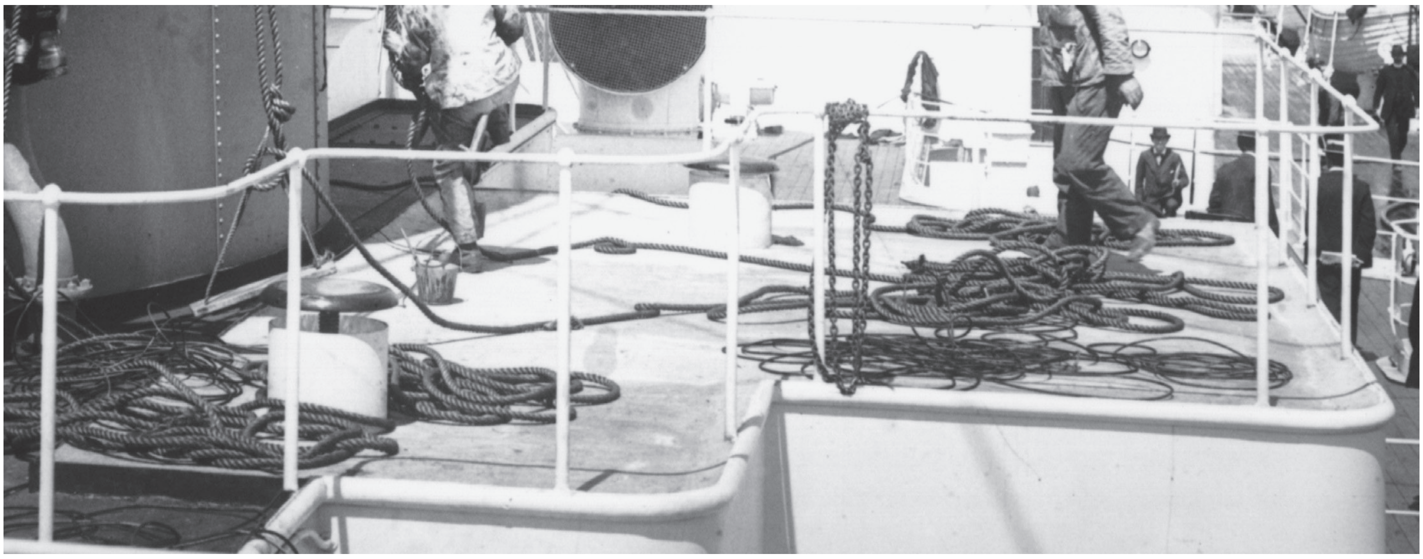


Fig. 10-16 **Roof Over the Officers' Mess on *Olympic*** – In this 1911 picture can be seen the cement laid in the corners where the covering board met the perimeter. The top of the Nos 1 & 2 Boiler casing is visible to the left, painted in the typical dark gray color.

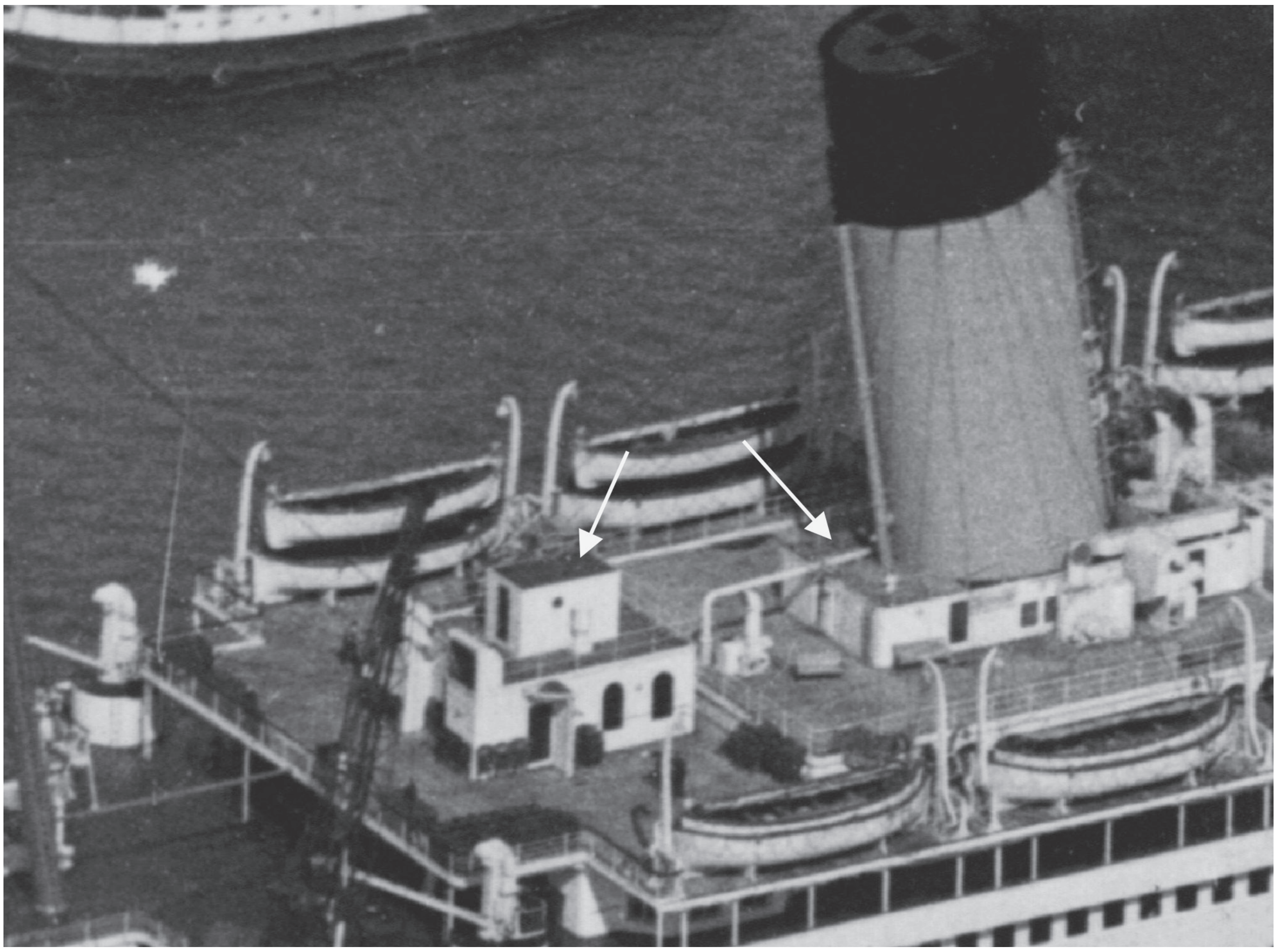


Fig. 10-17 **Roof of After Second Class Entrance on *Olympic*** – In this *Olympic* photograph from 1923, the roof of the elevator machinery house on top of the Second Class Entrance deckhouse can be seen (left arrow) and forward of it, the roof abutting the turbine engine casing beneath the No.4 Funnel (right arrow).

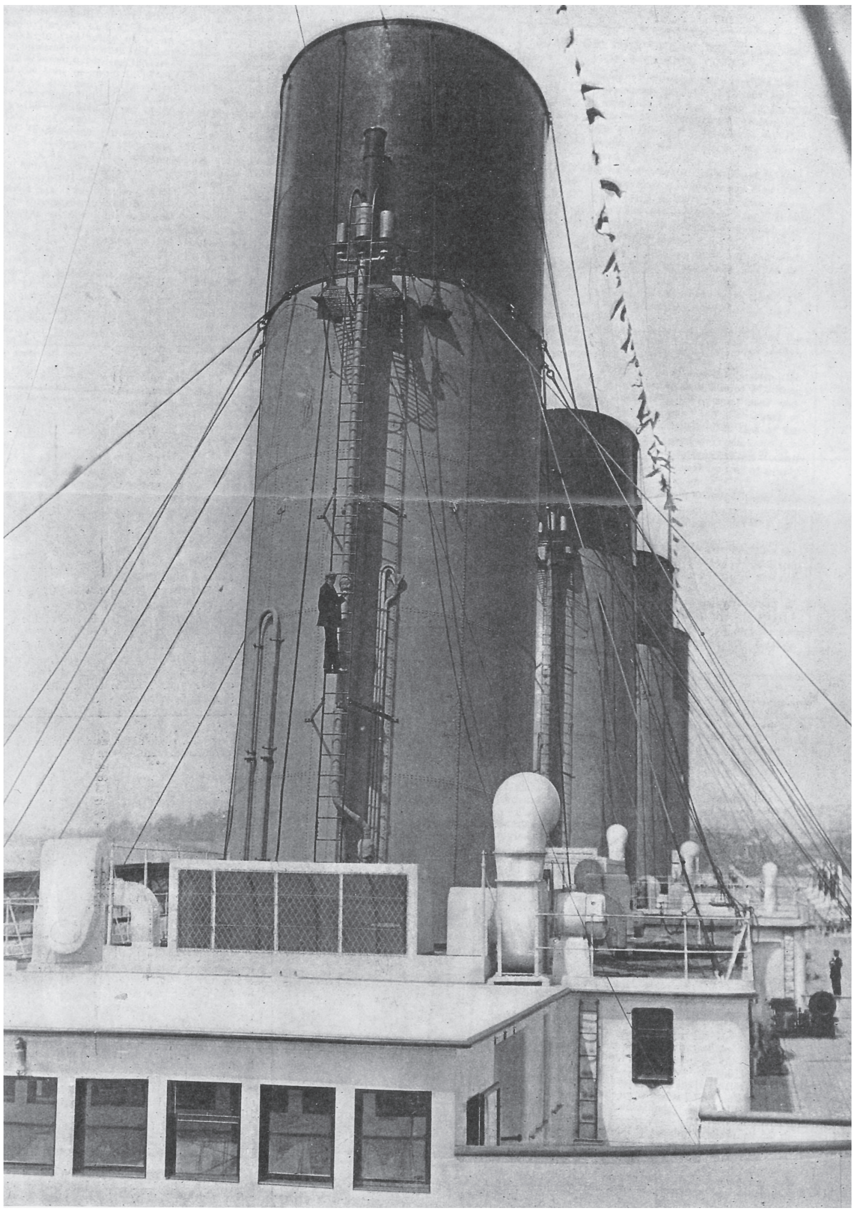


Fig. 10-18 **Navigating Bridge on *Olympic*** – *Olympic*'s Navigating Bridge, seen early in her career. The roof is painted white here and there appears to be a covering board or canvas ducking in place. In any case, it is clearly not bare tongue-and-groove planking alone as some researchers had believed. *(Daniel Klistorner collection)*

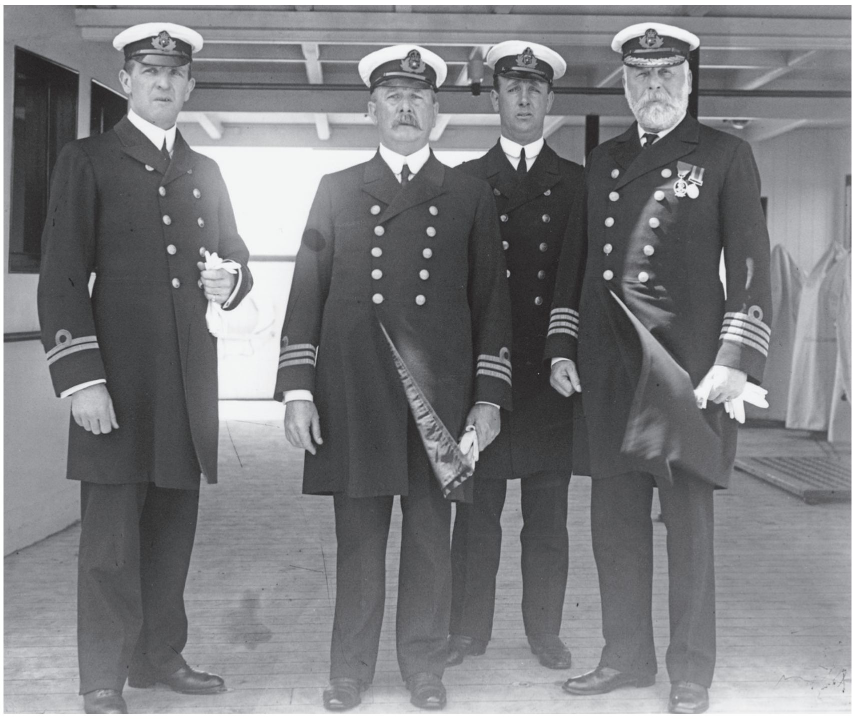


Fig. 10-19 **Captain Smith and Officers of *Olympic*, June 1911** – The Captain and three of his officers for *Olympic*'s maiden voyage. From left to right: 1st Officer William Murdoch (later of *Titanic*), Chief Officer Joseph Evans, 4th Officer David Alexander, and Captain Edward J. Smith. The tongue-and-groove boards lining the interior bulkheads of the Navigating Bridge shelter are visible behind them. Recessed into the deck planks at the men's feet are the brass sockets for the portable teak boards used to provide additional protection to the interior of the shelter in severe weather.

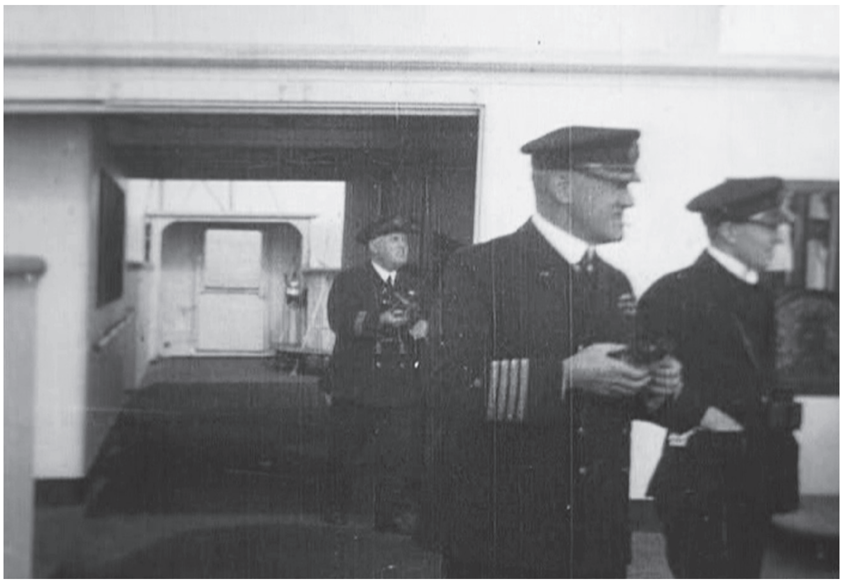


Fig. 10-20 **Captain Hayes on *Olympic*** – Captain Sir Bertram Fox Hayes, Captain of *Olympic*, as seen in an original White Star Line promotional film made in the early 1920s. The openings on both sides of the Wheelhouse are seen here in this rare view looking across at the port side Bridge wing cab. At the head beam of the opening can be seen four fittings to secure the portable boards used for closing off the bridge in bad weather.

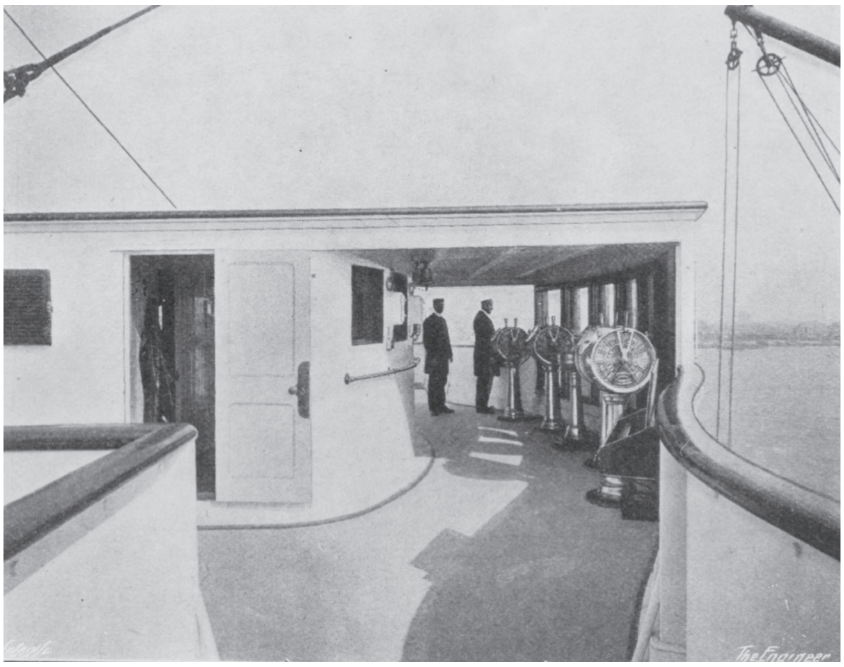


Fig. 10-21 **Bridge of the *Oceanic*** – The Navigating Bridge shelter and Wheelhouse of the *Oceanic*, photographed from the starboard Bridge wing. Shown in this picture is the starboard-side entrance door to the Wheelhouse, minus the round bull's-eye light. As with the *Oceanic*, the entrance doors into *Olympic*'s Wheelhouse initially had no windows; a situation which was changed only later in her career. The basic bridge layout of the *Olympic*-class liners was common to many of the ships built by Harland & Wolff in that era, and although some modern-day maritime historians feel the layout was poorly designed, apparently both Harland & Wolff and their various customers felt otherwise as this design served well for many years. *(*The Engineer*/ Authors' collection)*

Notes

1. The principal straining forces alluded to here – 'hogging', 'sagging', 'racking' and 'torsional stresses' – are individually defined in the glossary.
2. Harland & Wolff referred to the partially enclosed structure amidships protecting *Titanic*'s 'Navigating Bridge' as the 'Navigating Bridge shelter.'
3. 2ft 6in was standard shipbuilding practice, but due to *Titanic*'s size, the 3ft interval of her frames may have been used.
4. *Britannic*'s forward-facing windows were specified to be alternating fixed and vertical-sliding windows. The same may have been true for *Olympic* and *Titanic*.

Chapter 11

Sidelights, Skylights and Windows

Sidelights

The terms used to describe the parts and fittings of the round windows and openings in a ship varied depending on the shipyard and the county of origin. Most landsmen are conversant with the term 'porthole' – an opening in the side of a ship or deckhouse, usually round in shape, and fitted with a hinged frame in which one or more glass pane(s) are secured. 'Sidelight', on the other hand, is the term used to describe the glass and framework attached to a porthole to provide light and ventilation to the interior of the ship. Sidelights varied in design. Typically, a fixed brass frame was bolted or riveted to the shell plating and a separate frame holding the glass was hinged to it; in this manner it could be opened as desired to permit the exchange of air. The closure was made watertight by pivoted bolts that pressed a V-shaped projection on the one frame against an India-rubber packing ring in the other.[1]

Sidelights vulnerable to broken glass caused by high seas were supplied with a portable plug in the form of a disc of cast steel, to be installed in heavy weather. It was fitted from within and held in position by small projecting lips on the fixed porthole frame.

Because this type of plug was not integral to the watertight glass-holder frame, it was not designed to be watertight but, if necessary, could be made so with putty and yarn. The sidelights of the C Deck staterooms that looked out onto the forward Well Deck were also provided with plugs which were mounted externally. These were quite strong, as they needed to withstand the repeated onslaught of boarding seas.[2] These same plugs – also referred to as 'deadlights' – were also used at night to block all light from within. At sea, the ship would normally be dark forward of the Bridge, and the escape of any light would affect the safety of the ship by compromising the night vision of the officers and crew. For this reason all sidelights forward of the Bridge were normally darkened in this manner.

As a provision against the breaking of the glass and the entrance of sea water, an inner watertight cover called a 'shutter' with an India-rubber packing ring

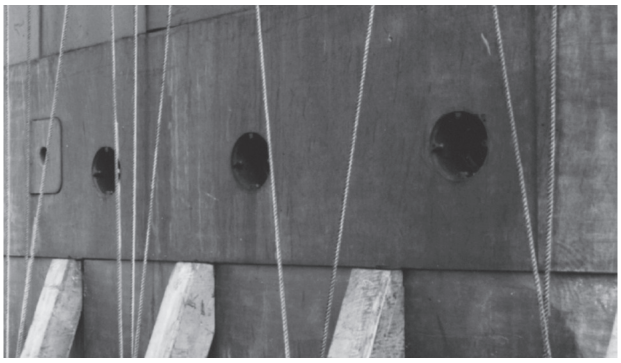


Fig. 11-1 **Projecting Lips for Plug** – Three portholes showing the projecting lips used to secure the cast iron plugs. *(H&W/Authors' collection)*

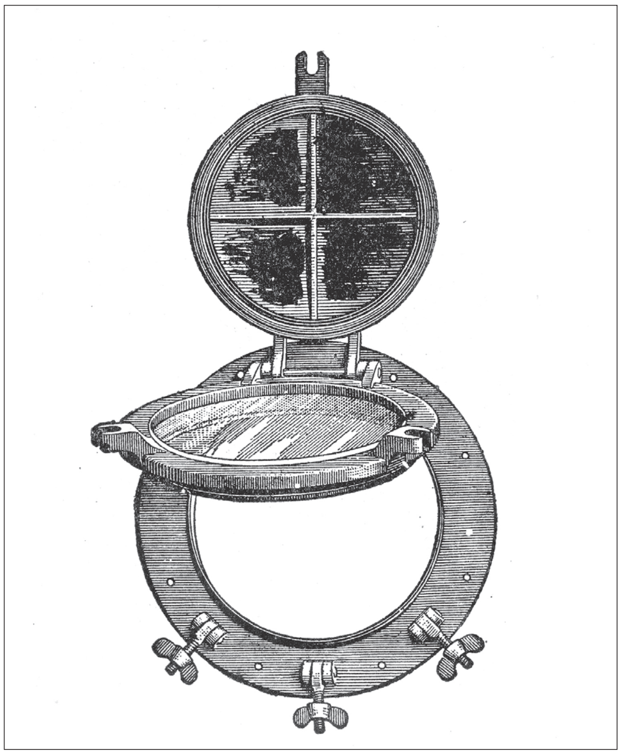


Fig. 11-2 **Sidelight Illustration** – Drawing of an ordinary sidelight showing the shutter installed. The shutters on White Star Line ships each had a five-point star cast within the fitting (not shown here).

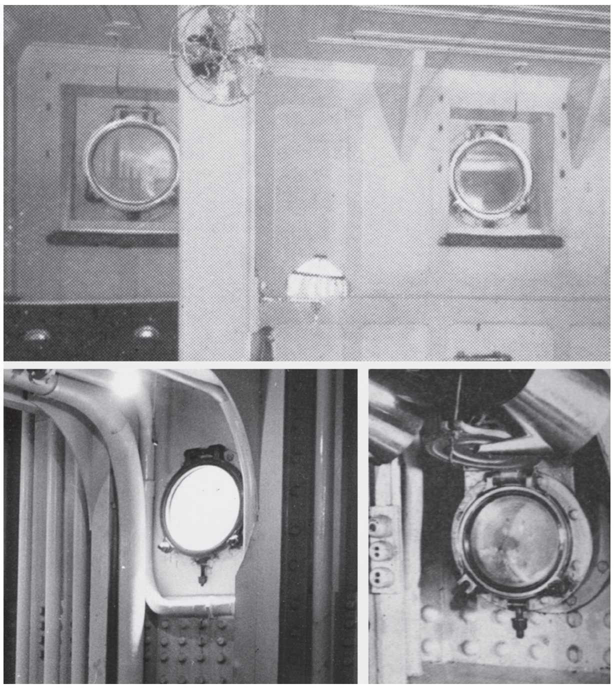


Fig. 11-3 **Sidelight Comparison** – The upper photograph was taken on *Olympic* in the 1930s. Although by this point changes had been made in the way of passenger accommodations, the sidelights remained unchanged. In this image the shutter has been removed, though the wire to secure it in the open position is present. Just as on modern cruise ships, the shutters within cabins could be removed and stowed somewhere within easy reach. The blinds are shown here mounted at the bottom of the sidelight because the frame for the sidelight glass was hinged at the top and swung up. (Note also the three positions for fastening the blinds.) This arrangement appears to have been a later addition to *Olympic* because blinds are not seen in photographs from either ship leading up to the time of the *Titanic* disaster. The image at lower left is from *Olympic*'s Swimming Bath. Again, the shutter has been removed, but the brackets are visible. (In most pictures of *Olympic*'s Swimming Bath, the shutters are present.) The image at lower right is of a ventilating sidelight from the galley pantry of another White Star Line ship. The shutter is seen here in the open position, and the cast star is just visible on the inside of the cover; these could be seen from outside the ship when the shutter was closed. *(All images Daniel Klistorner collection)*

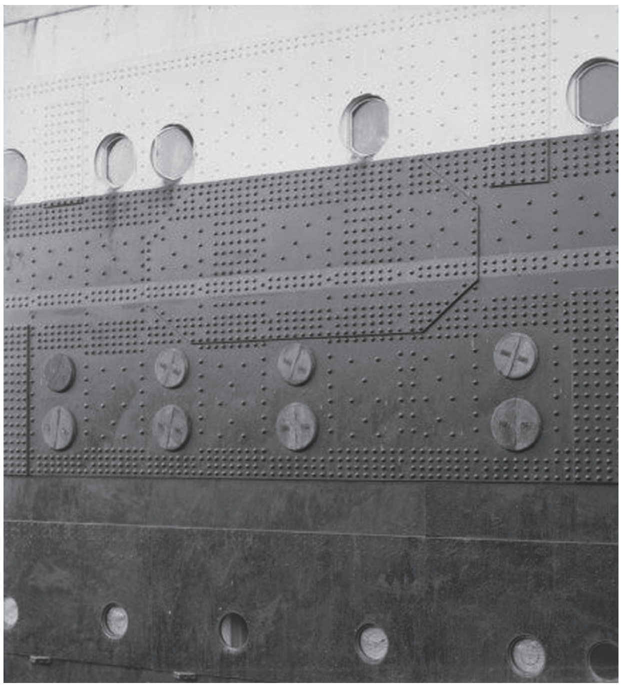


Fig. 11-4 **Plugs and Shutters** – In December 1921, *Olympic* ran into a fierce Atlantic storm which damaged some of her D Deck sidelights. This image shows them in the aftermath of this incident, with wooden protective plugs in place over the damaged sidelights. The Utley's Pivoting Sidelights can be seen at the top of the image. In the lowest row of sidelights visible here, the shutters are in place with the cast 5-point stars visible through the glass.

was often provided; it was hinged to the fixed frame and was hove up by one or more tightening screws. It was not uncommon to find the sidelight frame absent of its shutter if one was intended to be fitted, as they were often portable. This was particularly true of sidelights within the better passenger accommodations, where the sidelights were boxed-in by interior joinery and where wooden jalousies or other forms of internal window coverings were used to keep out sunlight, as all of these prevented the proper stowage of hinged shutters.

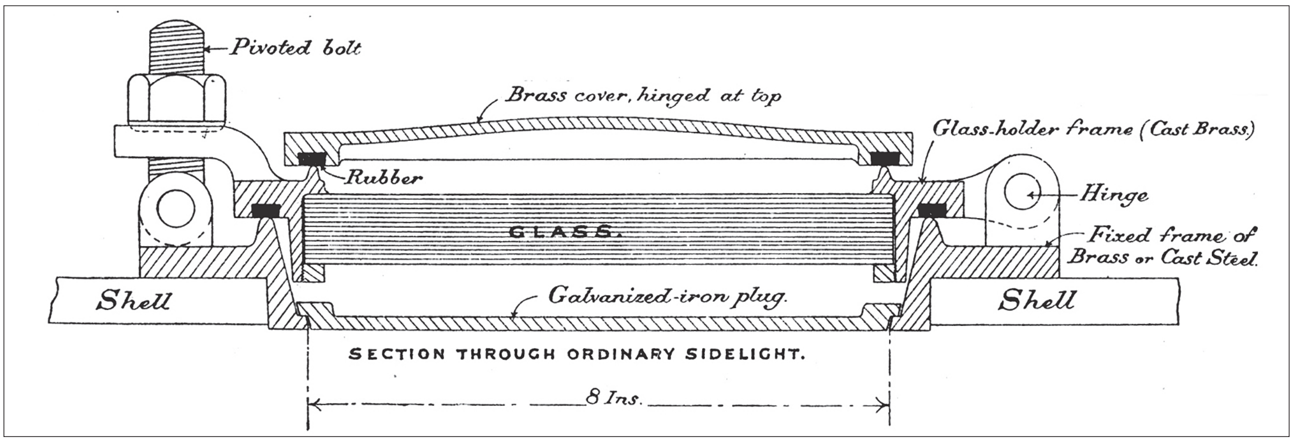

Pivoted bolt
Brass cover, hinged at top
Glass-holder frame (Cast Brass)
Rubber
Hinge
GLASS.
Fixed frame of Brass or Cast Steel.
Shell
Shell
Galvanized-iron plug.
SECTION THROUGH ORDINARY SIDELIGHT.
8 Ins.

Fig. 11-5 **Section Through Ordinary Sidelight**. *(*Practical Shipbuilding*/Authors' collection)*

Most of *Titanic*'s sidelights were manufactured by Harland & Wolff, with Thomas Utley Ltd providing those of special design.

The diameter of the visible glass varied from 9 to 17in, with a glass thickness from 1 to 1¼in. Specifically, sidelights of 9in diameter utilized 1in glass; sidelights between 10 and 14in diameter, from 1 to 1¼in glass; and sidelights of 15in diameter to the Utley's Patent 19¾in x 24in pivoting sidelights (discussed later), 1¼in glass. Sliding glass windows were generally 1¼in thick. The size of sidelight fitted depended on both the class of accommodation and the location in the hull; the glass varied in thickness depending on the area in which it served. The smaller diameters were fitted at the forward and after ends of the ship, with the larger ones fitted amidships. All sidelight frames were built both massive and strong as they were frequently subjected to severe blows from waves. The sidelights in the Third Class accommodations on F and G Decks towards the bow (located forward of the No.3 Hatch) were also fitted externally with safety bars to protect them from the anchor cables, as this was the point in which the hull made the transition from the hollow, inward curvature of the bow to the nearly flush flanks of the midbody.

The Board of Trade regulations regarding sidelights came from the Board of Trade's Bulkhead Committee. An excerpt of the rules in effect in 1912 follows:

> *[it is required] that all sidelights fitted in coalbunkers and bunker holds are to be fixed. That the glass in such sidelights have a thickness of not less than one-half of their clear diameter, be enclosed in a sufficiently strong frame, and be recessed not less than 1in within the outer surface of the shell plating. That sidelights the sills of which are at a distance from the bulkhead load line less than one-fourth of the bulkhead freeboard be not opened at sea except when, through the consumption of coal or otherwise, the vessel has lightened so much as to make the freeboard to the sills of the sidelights greater than one-fourth of the bulkhead freeboard, and in that case the provisions of subsection (d) may be held to apply. That ventilators in the vessel's side capable of closing automatically in case of submersion as well as by hand may be fitted, provided the sill of the opening on the inside be not within 2ft of the load line, but that any such automatic arrangement should be examined at least once a week, and if not in order it should be closed.*
>
> *(d) That all other sidelights and ports below the bulkhead deck*[3] *be of sufficient strength. They may be fixed or capable of being opened, but in the latter case the sidelights as well as the ports, if any, should not be adapted to be opened by passengers, they should be closed before the vessel puts to sea, but may be opened during the voyage by the master's special orders if the sill be not less than one-fourth of the bulkhead freeboard above the load line. The time of and reason for opening, and also the time of closing such sidelights and ports, should be noted in the official logbook. All sidelights, except those immediately under the bulkhead deck, and bull's-eye sidelights should be fitted with hinged metal covers.*
>
> *(e) That sidelights immediately under the bulkhead deck may be capable of being opened by passengers provided they be arranged to close automatically in case of submersion as well as by hand.*

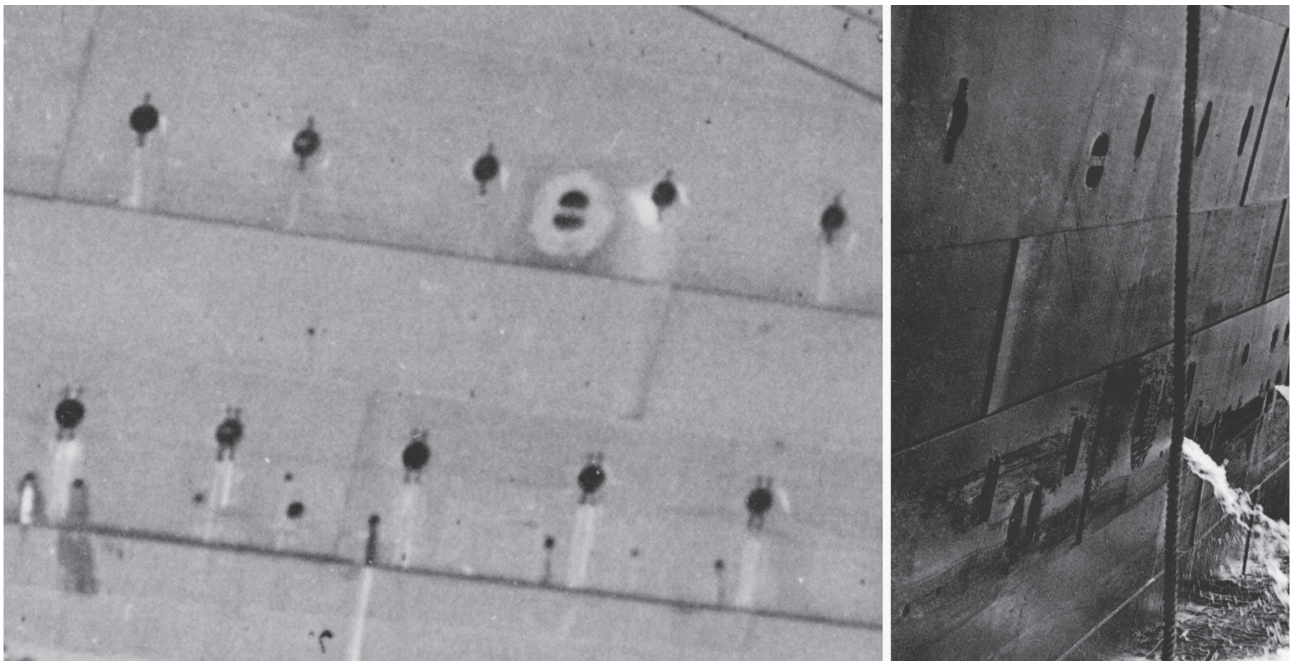


Fig. 11-6 **Safety Bars** – At left, *Titanic*'s port-side safety bars; at right, the starboard-side safety bars. These were permanently installed over the sidelights as a protection against the cables when riding at anchor. *(Right image Father Browne photograph; both images from authors' collection)*

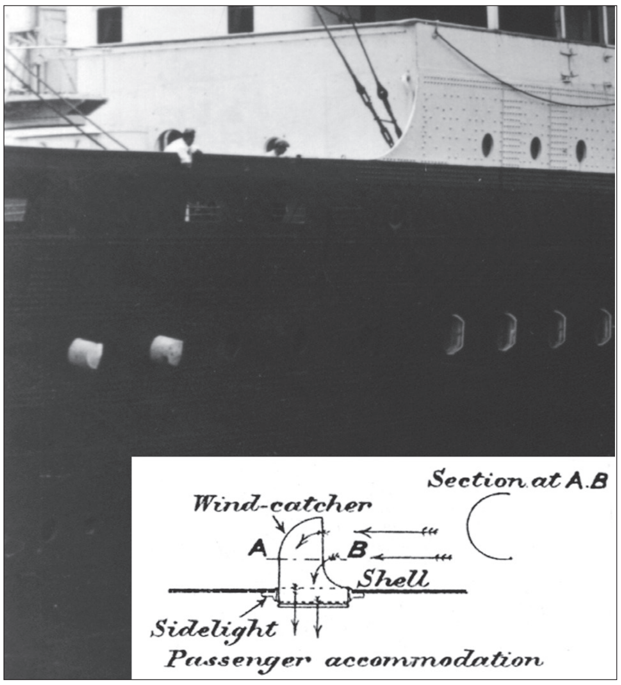

Section at A.B
Wind-catcher
A
B
Shell
Sidelight
Passenger accommodation

Fig. 11-7 **Wind Catchers** – Drawing of a typical wind catcher, and a view of them being employed on *Olympic*; here, they appear as white inserts extending out from the side of the hull through the portholes. The sidelights seen to the right of the two wind catchers are Utley's Patent Pivoting Sidelights of the First Class staterooms on D Deck. *(Image from authors' collection; drawing from* Practical Shipbuilding*)*

> *(f) That notwithstanding the foregoing provisions to the contrary, sidelights and ports immediately under the bulkhead deck may be under the control of the crew or passengers, and need not be arranged to close automatically, provided the freeboard for the purpose of bulkhead spacing is measured not from the bulkhead deck, but from a line $^{3}/_{100}$ths of the depth amidships below the line of the sills of any such sidelights and ports.*

A sidelight, when opened, also provided ventilation to the room inside. In the era before climate-controlled ventilation systems, this was every bit as important as the provision of light. While ships such as *Titanic* relied primarily on mechanically-assisted ventilation systems, the ventilation of the cabins next to the side of the vessel was augmented by sidelights. In addition, when it was desirable to provide supplementary ventilation beyond that provided by open sidelights, metal wind catchers could be employed to direct fresh air to the interior of cabins and other spaces.

On *Titanic*, for areas situated near the water line, in lavatories, and in crew accommodations, ordinary sidelights were not advisable because, if left open and/or unattended in heavy weather, the ship risked

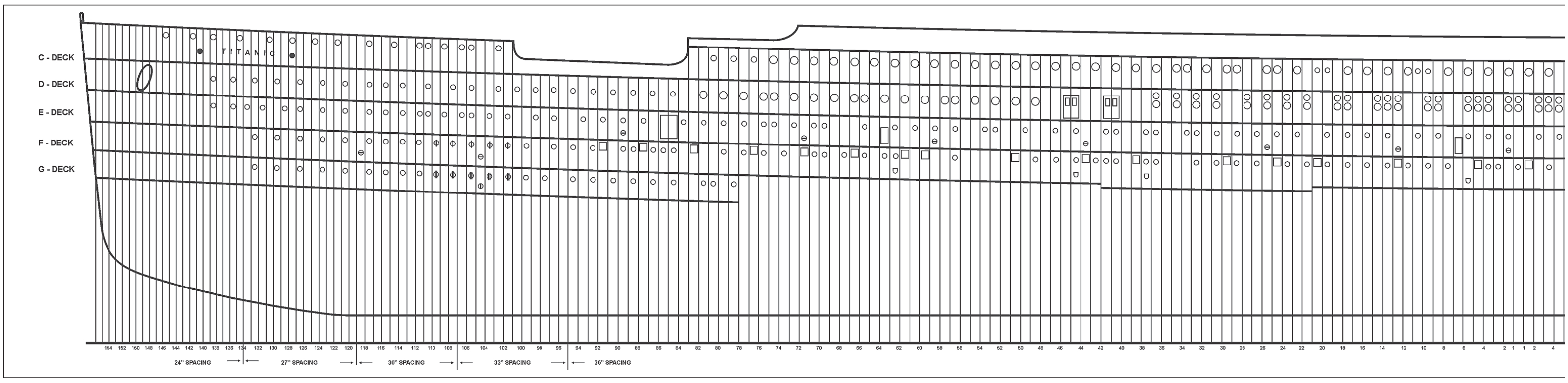

C - DECK
D - DECK
E - DECK
F - DECK
G - DECK
TITANIC
24" SPACING
27" SPACING
30" SPACING
33" SPACING
36" SPACING

Fig. 11-9 **Sidelight Locations, Port Side**. *(Illustration by Bruce Beveridge)*

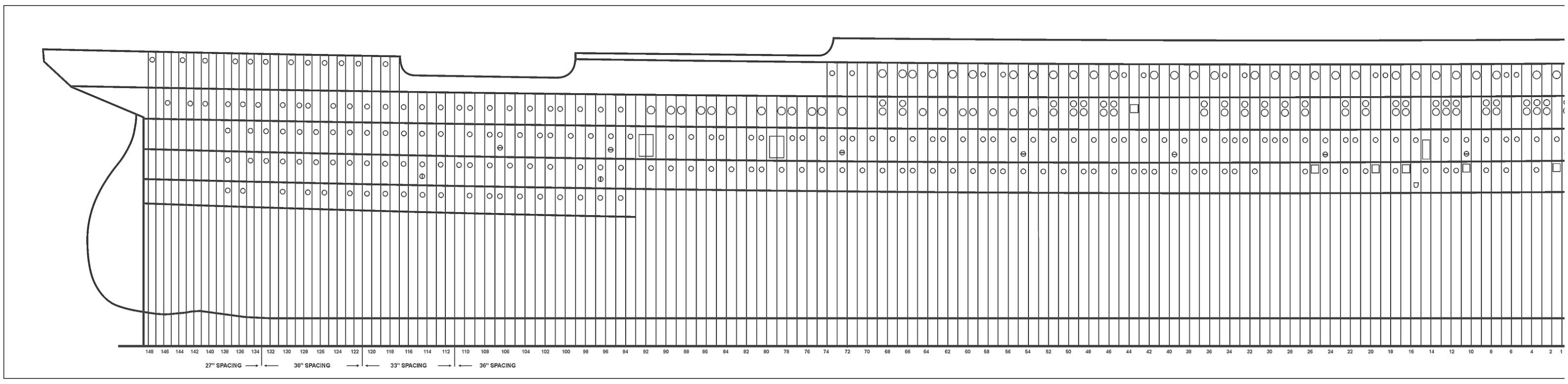

27" SPACING
30" SPACING
33" SPACING
36" SPACING

Fig. 11-10 **Sidelight Locations, Starboard Side**. *(Illustration by Bruce Beveridge)*

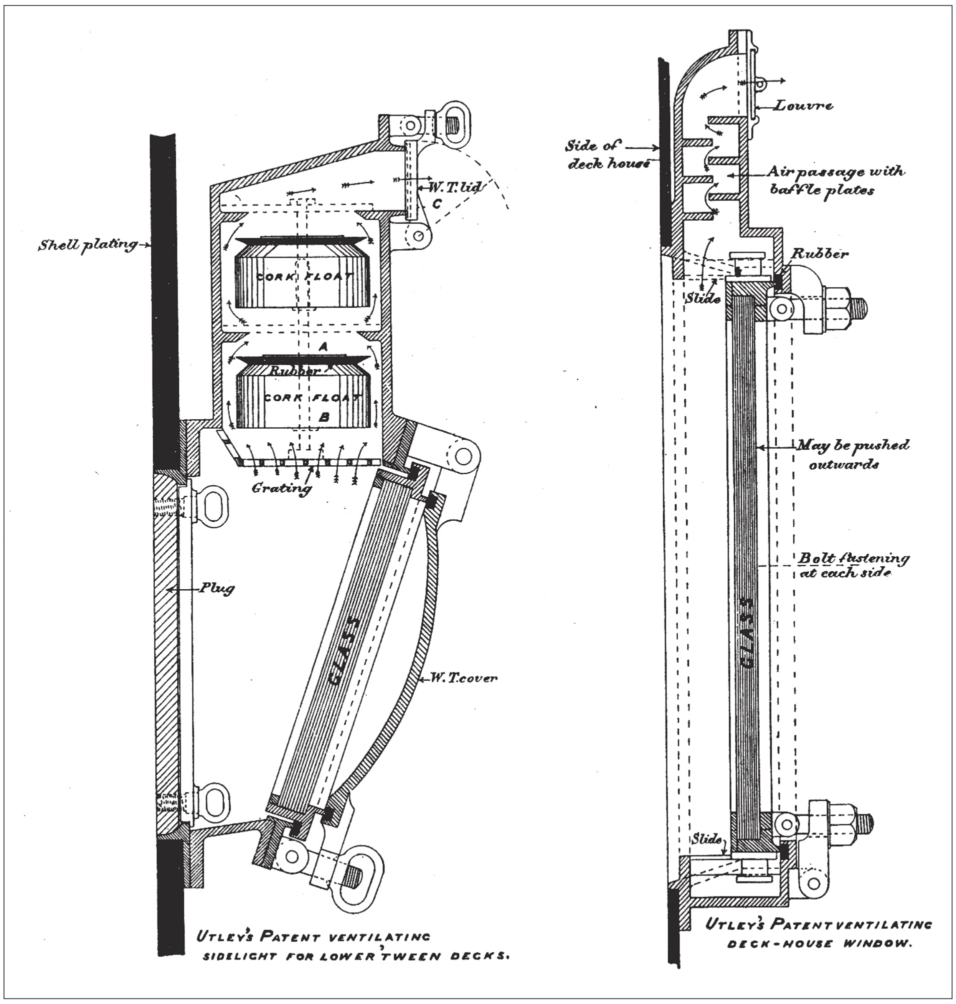
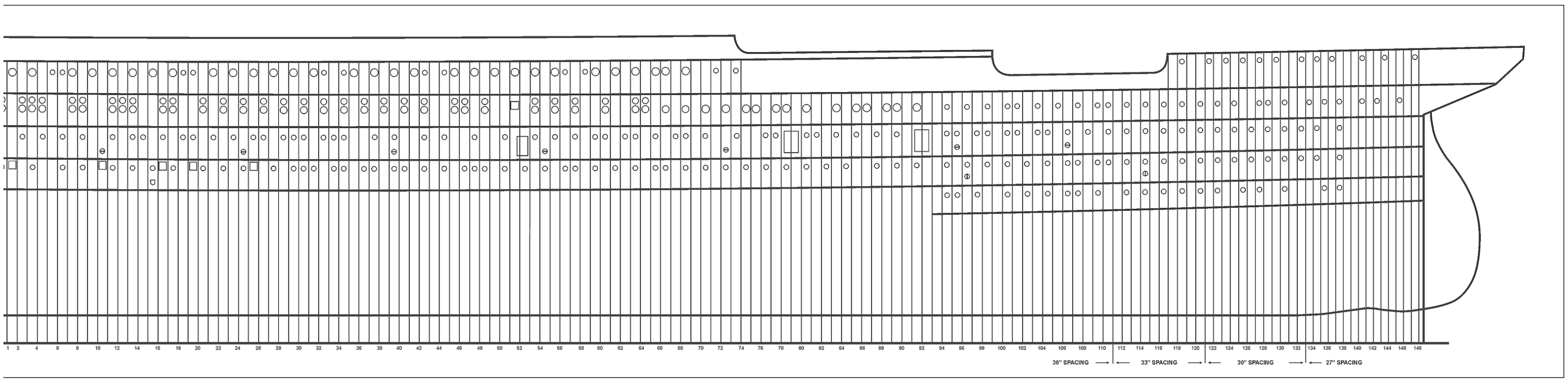
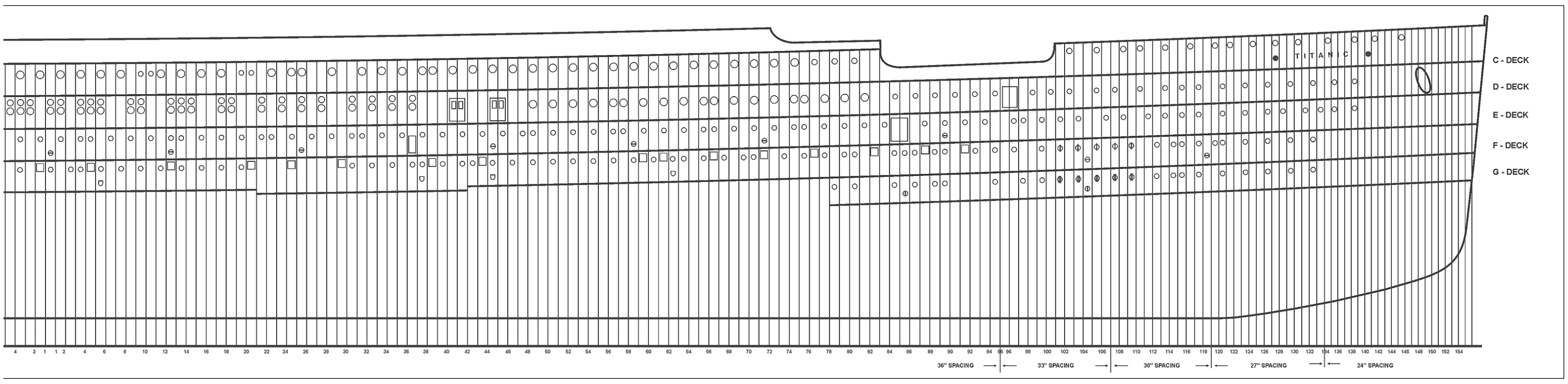

Shell plating
W. T. lid
C
CORK FLOAT
A
Rubber
CORK FLOAT
B
Grating
Plug
GLASS
W. T. cover
UTLEY'S PATENT VENTILATING SIDELIGHT FOR LOWER 'TWEEN DECKS.
Louvre
Side of deck house
Air passage with baffle plates
Rubber
Slide
May be pushed outwards
Bolt fastening at each side
GLASS
Slide
UTLEY'S PATENT VENTILATING DECK-HOUSE WINDOW.

Fig. 11-8 **Utley's Ventilating Sidelight** – Two versions of the Utley's Ventilating Sidelight. The version to the right is similar to one that has been raised from the *Titanic* wreck site. *(Drawing from* Practical Shipbuilding; *image from authors' collection)*


36" SPACING
33" SPACING
30" SPACING
27" SPACING


TITANIC
C - DECK
D - DECK
E - DECK
F - DECK
G - DECK
36" SPACING
33" SPACING
30" SPACING
27" SPACING
24" SPACING

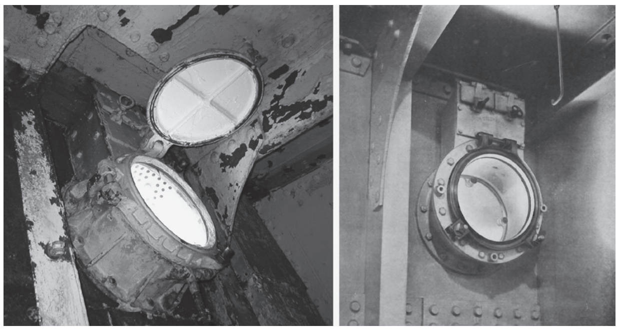


Fig. 11-11 **Utley's Ventilating Sidelight on Private Yacht** – At left, an Utley's Ventilating Sidelight as fitted in a private yacht. At right, one on *Olympic* as seen in 1911. *(Left image courtesy T. M. Utley Offshore, plc; right image from authors' collection)*

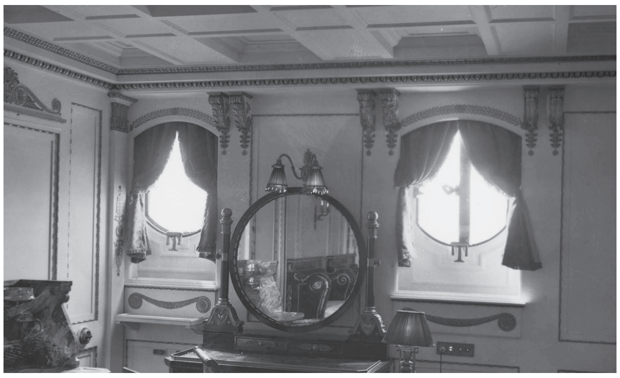


Fig. 11-12 **Utley's Pivoting Sidelight** – The C Deck Utley's Pivoting Sidelights on *Olympic*, as seen from inside. (*Daniel Klistorner Collection)*

flooding from water entering in rough seas. In these locations, Utley's Patent Ventilating Sidelights were fitted. These exchanged air not by means of opening a hinged glass frame, but via an air passage that was closed automatically by a buoyant float whenever swells or the rolling of the vessel submerged the sidelight. The ventilating mechanism had a small door located at the top of the frame fitted with thumbscrews to manually shut off the airflow by sealing the cover. The ventilating ports differed in design as needed to accommodate the curve of the hull at the bow and stern of the ship.

The sidelights providing the most effective ventilation, though, were the patented Utley's Pivoting Sidelights, fitted to the First Class staterooms on C Deck, on D Deck forward, and in the Second Class Dining Saloon on D Deck aft.

These large-diameter ports had flat (straight) edges fore and aft, with the glass frame pivoting vertically on a central shaft. They were opened by the use of a dog screw located along the inner frame. By swivelling the pane, half of it projected out beyond the vessel's side, and depending on the direction in which the frame was angled, air could be either directed into the stateroom or drawn out by induction.

These sidelights were specially designed for strength. When the sidelight was closed, the glass frame was hove tight by an inward pull so that a blow from a wave would

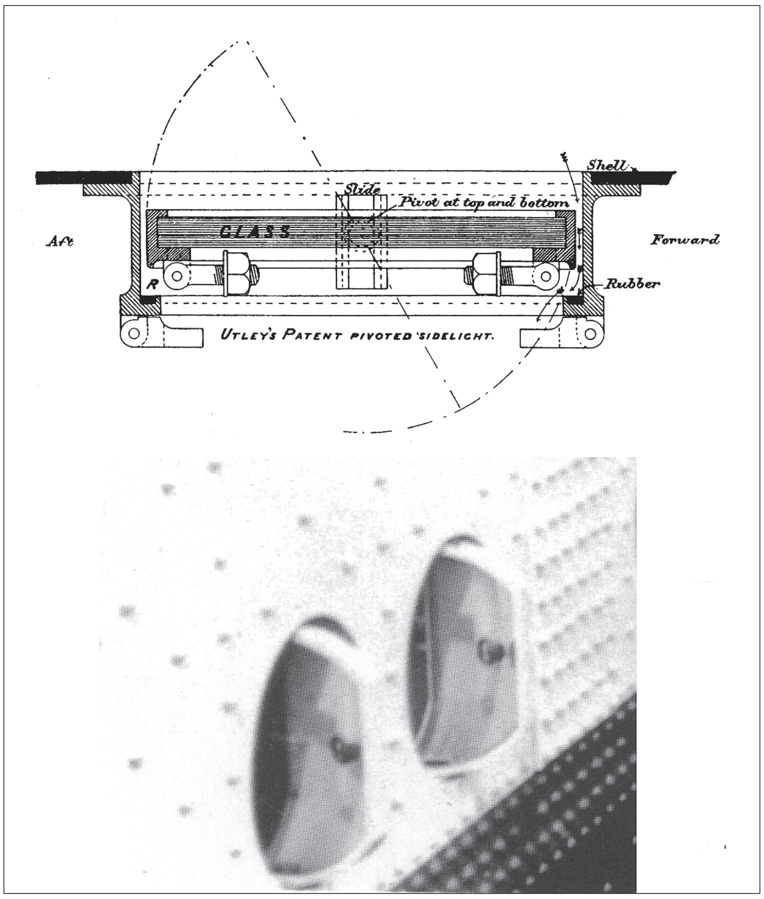


Fig. 11-13 **Utley's Pivoting Sidelight** – Utley's Patent Pivoting Sidelights were used on C Deck and D Deck. *(Illustration from* Practical Shipbuilding; *image from authors' collection)*

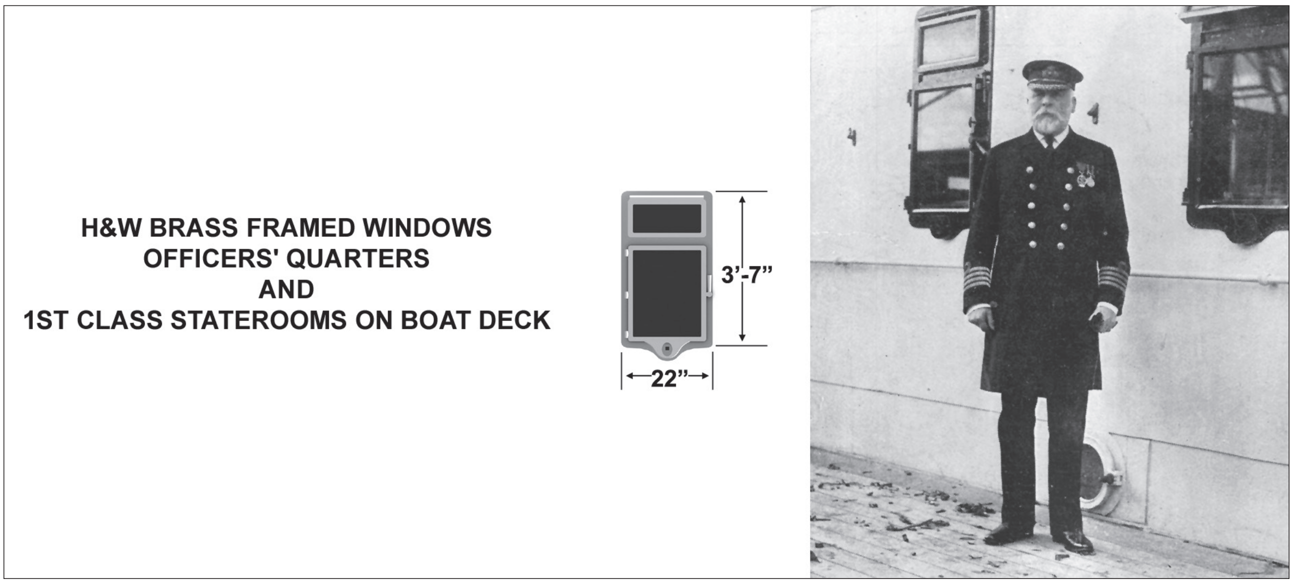

H&W BRASS FRAMED WINDOWS
OFFICERS' QUARTERS
AND
1ST CLASS STATEROOMS ON BOAT DECK
3’-7”
22”

Fig. 11-14 **Officers’ Quarters Deckhouse Windows and Skid Lights** – At right, Captain Smith stands in front of two of the windows on the starboard side of the Officer’s Quarters deckhouse on *Titanic*’s Boat Deck. At his feet is one of the skid lights that admitted natural light and ventilation to the inner A Deck staterooms below. *(Illustration by Jason DeDonno; image from authors’ collection)*

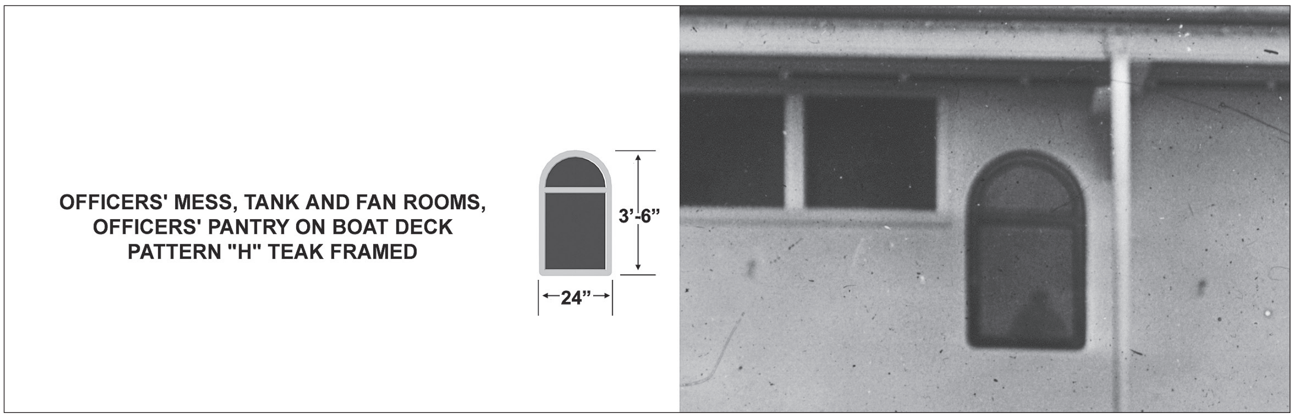

OFFICERS' MESS, TANK AND FAN ROOMS,
OFFICERS' PANTRY ON BOAT DECK
PATTERN "H" TEAK FRAMED
3’-6”
24”

Fig. 11-15 **Pattern ‘H’ Windows.** *(Illustration by Jason DeDonno; image from authors’ collection)*

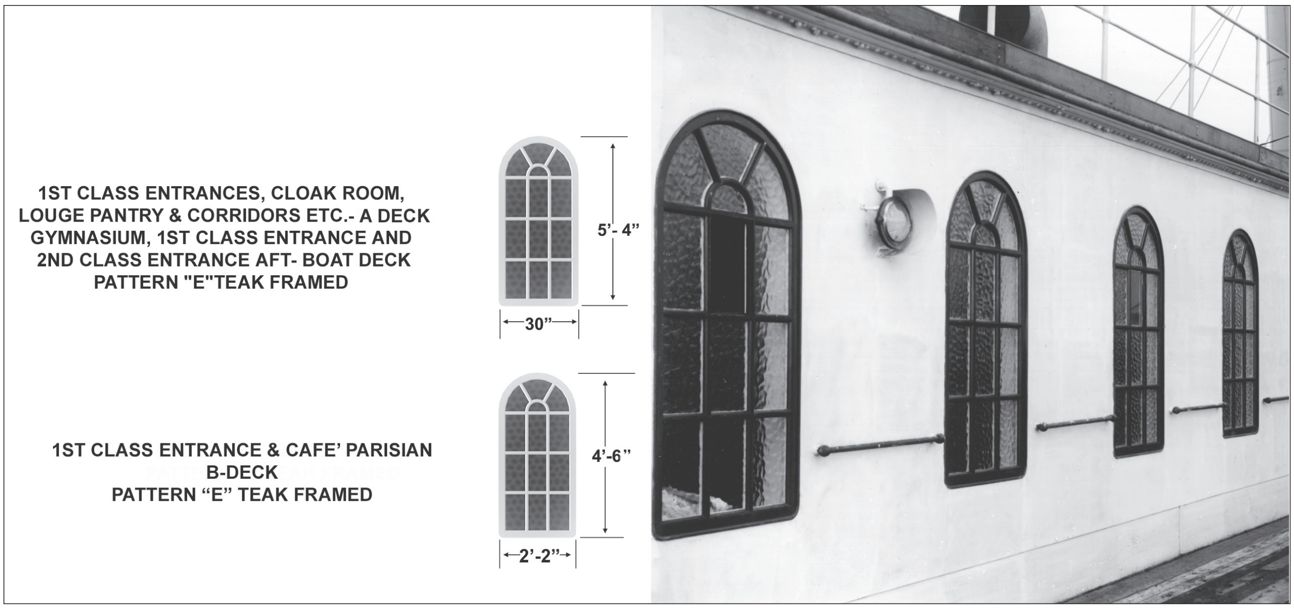

1ST CLASS ENTRANCES, CLOAK ROOM,
LOUGE PANTRY & CORRIDORS ETC.- A DECK
GYMNASIUM, 1ST CLASS ENTRANCE AND
2ND CLASS ENTRANCE AFT- BOAT DECK
PATTERN "E"TEAK FRAMED
5’- 4”
30”
1ST CLASS ENTRANCE & CAFE’ PARISIAN
B-DECK
PATTERN “E” TEAK FRAMED
4’-6”
2’-2”

Fig. 11-16 **Pattern ‘E’ Windows** – The Gymnasium windows were special in that they had Flemish glass, with the exception of a clear-glass center pane in alternate windows; these center panes were reportedly the only ones that could be opened. *(Illustration by Jason DeDonno; image from authors’ collection)*

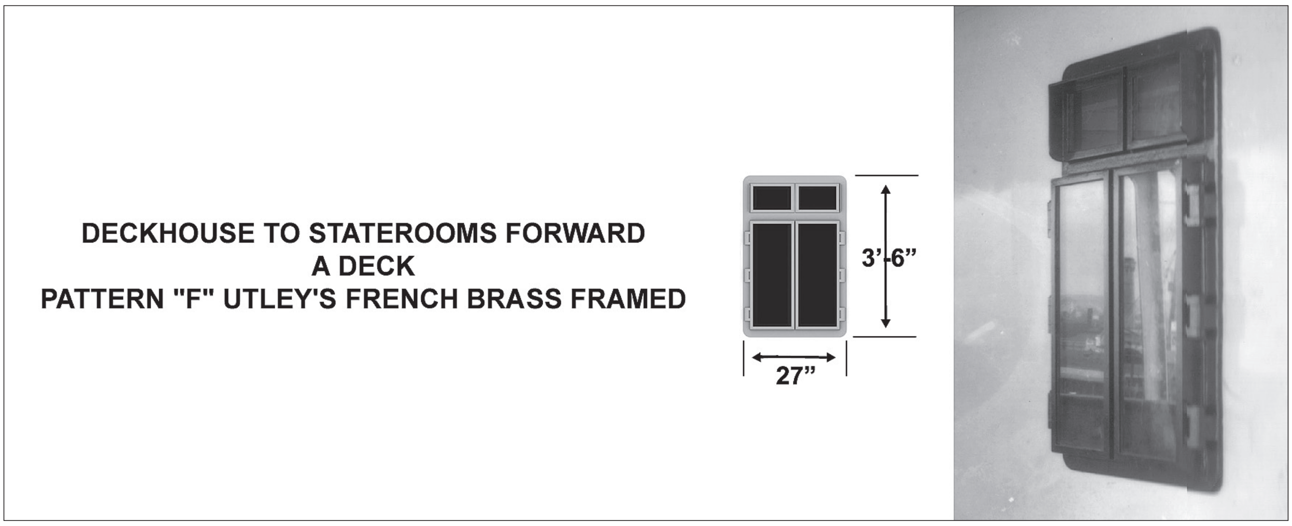

DECKHOUSE TO STATEROOMS FORWARD
A DECK
PATTERN "F" UTLEY'S FRENCH BRASS FRAMED
3'-6"
27"

Fig. 11-17 **Pattern 'F' Windows.** *(Illustration by Jason DeDonno; image from authors' collection)*

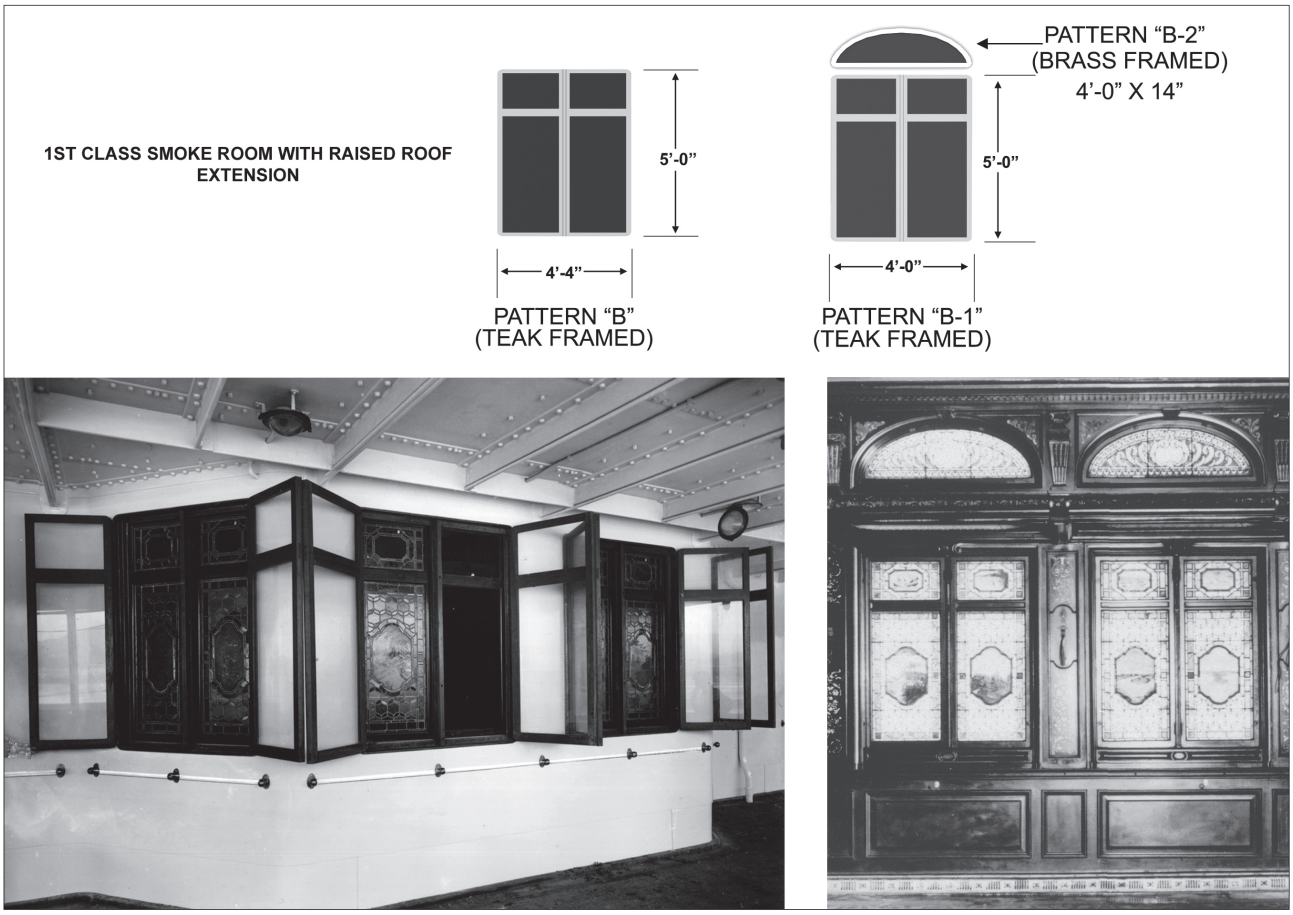

1ST CLASS SMOKE ROOM WITH RAISED ROOF EXTENSION
5'-0"
4'-4"
PATTERN "B"
(TEAK FRAMED)
PATTERN "B-2"
(BRASS FRAMED)
4'-0" X 14"
5'-0"
4'-0"
PATTERN "B-1"
(TEAK FRAMED)

Fig. 11-18 **Pattern 'B' Windows** – The First Class Smoke Room windows. At left, how they appeared from the A Deck promenade; at right, how they appeared from inside, with the raised roof extension through the Boat Deck visible at top. The external glazing was clear, while the decorative internal windows were leaded and stained glass in shades of amber and white. *(Illustration by Jason DeDonno; images from H&W/Authors' collection)*

not, as in an ordinary sidelight, strain the bolts and burst the light open, but instead would press it home more tightly against its seat.

Windows

It has been recorded in specification books that most of the large teak- and brass-framed windows on the top decks and fitted to the deckhouses were manufactured by Harland

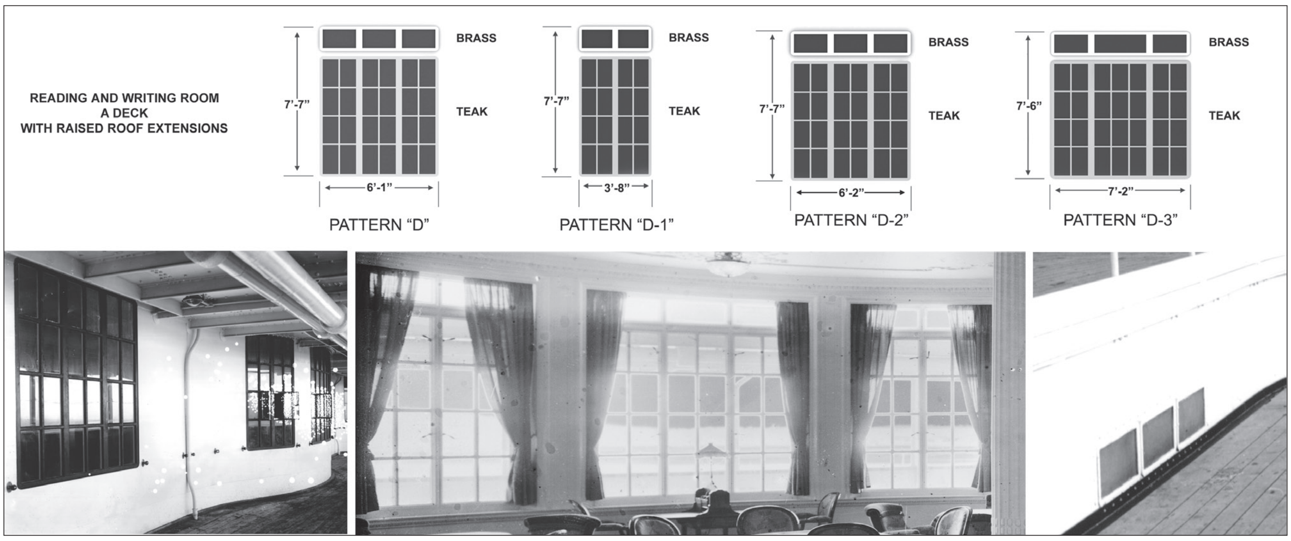

READING AND WRITING ROOM
A DECK
WITH RAISED ROOF EXTENSIONS
BRASS
TEAK
7'-7"
6'-1"
PATTERN "D"
BRASS
TEAK
7'-7"
3'-8"
PATTERN "D-1"
BRASS
TEAK
7'-7"
6'-2"
PATTERN "D-2"
BRASS
TEAK
7'-6"
7'-2"
PATTERN "D-3"

Fig. 11-19 **Pattern 'D' Windows** – The windows of the First Class Reading and Writing Room. At left, the windows viewed from the A Deck promenade; at center, their appearance from inside (also note the windows within the area of the raised roof extension through the Boat Deck). At right, an exterior view of the windows fitted in the raised roof extensions through the Boat Deck. *(Illustration by Jason DeDonno; images from H&W/Authors' collection)*

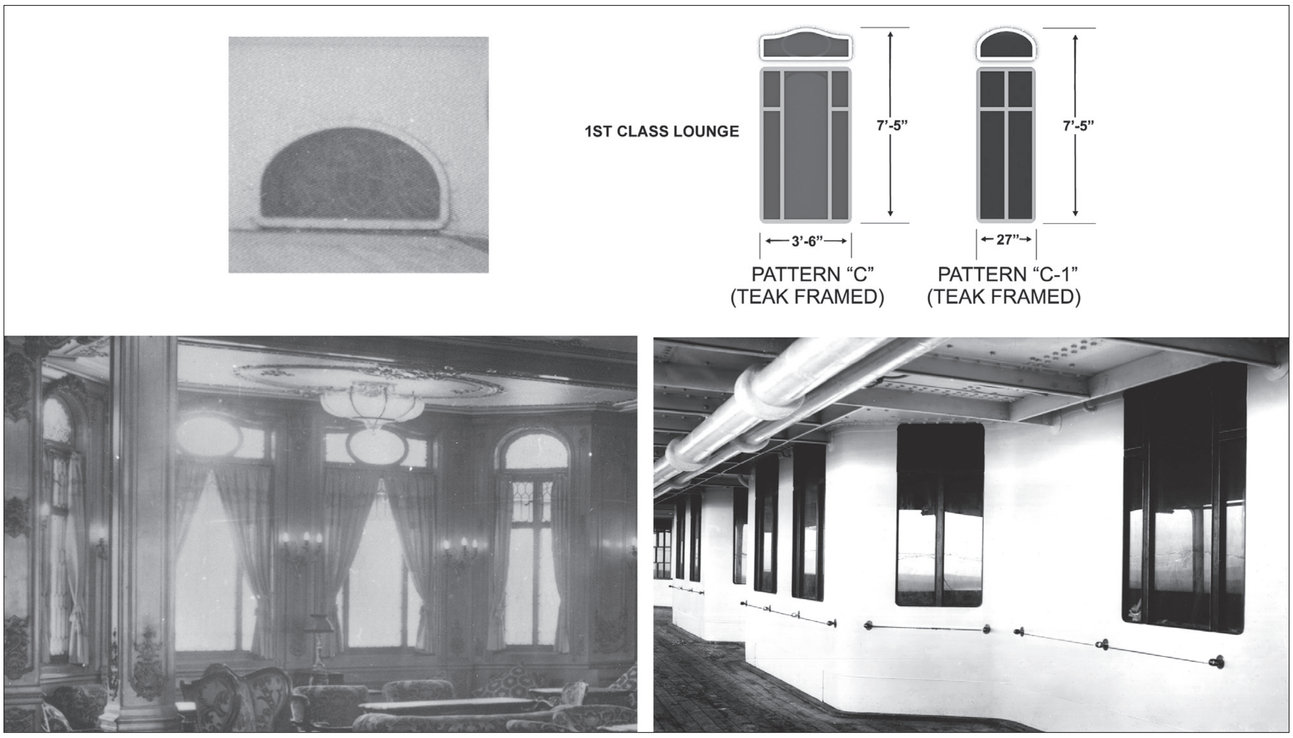

1ST CLASS LOUNGE
7'-5"
3'-6"
PATTERN "C"
(TEAK FRAMED)
7'-5"
27"
PATTERN "C-1"
(TEAK FRAMED)

Fig. 11-20 **Pattern 'C' Windows** – The windows of the First Class Lounge. At upper left, a view of the windows fitted in the raised roof extension as seen from outside; at lower left, how they appeared from inside. At right, the Lounge windows viewed from the A Deck promenade. As with the First Class Smoke Room windows, clear exterior glazing protected the decorative interior leaded-glass panels. *(Illustration by Jason DeDonno; images from H&W/Authors' collection)*

& Wolff. However, some, if not most, of these windows were probably made by outside contractors to Harland & Wolff's specifications. The Utley company, which is still in business at the time of this writing, has claimed that it produced all the teak-framed windows for *Olympic* and *Titanic*, and has stated that it possesses some of the original ordering notes of the Gymnasium-style windows.[4] These were categorized by letter designations that corresponded to descriptions and independent sizes found on the ship's construction plans. Many of the windows fitted to the *Olympic*-class vessels were custom built; however, there were some standard windows that were also installed on other Harland & Wolff-built ships, including vessels owned by companies other than the White Star Line.

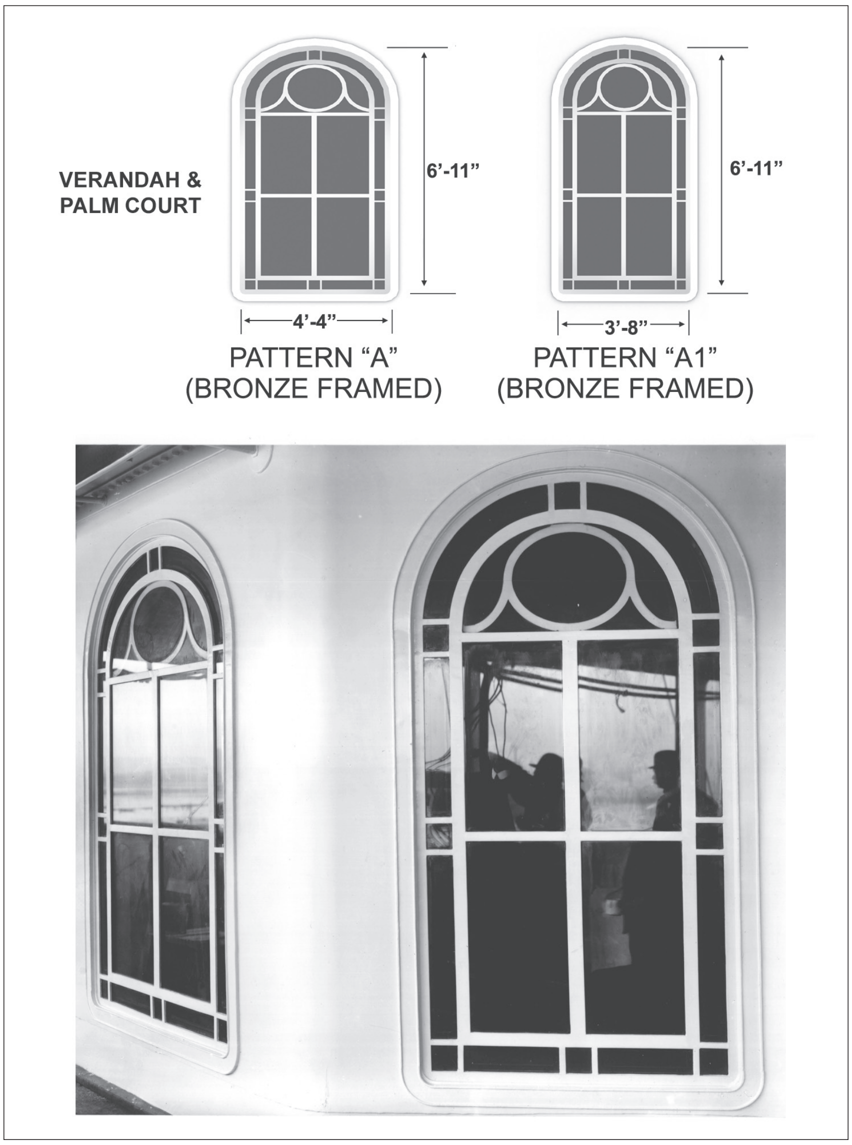

VERANDAH &
PALM COURT
6’-11”
6’-11”
4’-4”
3’-8”
PATTERN “A”
(BRONZE FRAMED)
PATTERN “A1”
(BRONZE FRAMED)

Fig. 11-21 **Pattern ‘A’ Windows** – The Verandah and Palm Court windows. *(Illustration by Jason DeDonno; image from authors’ collection)*

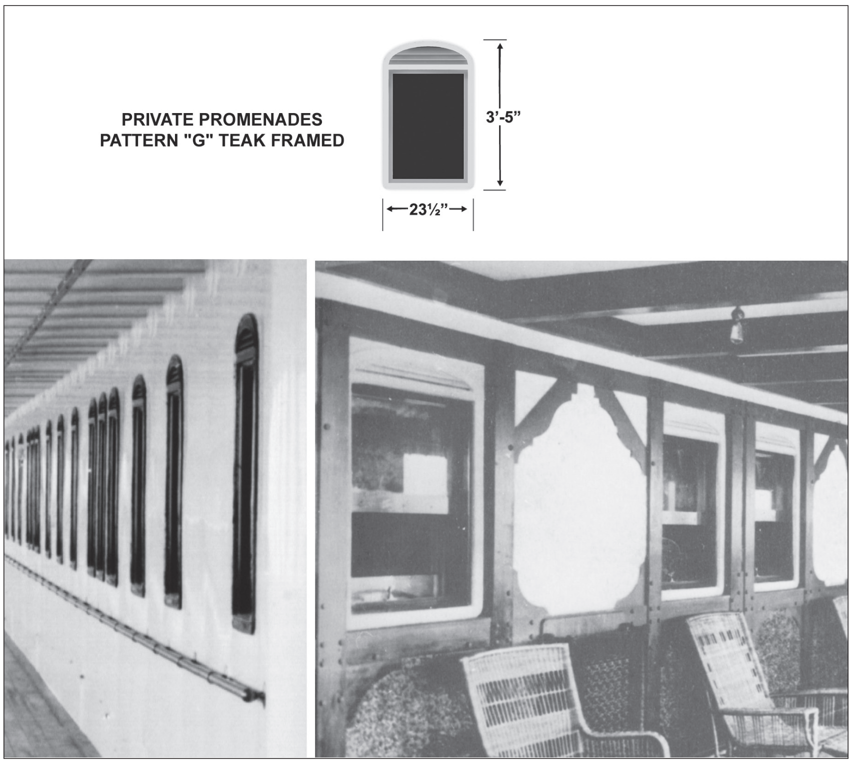

PRIVATE PROMENADES
PATTERN "G" TEAK FRAMED
3’-5”
23½”

Fig. 11-22 **Pattern ‘G’ Windows** – The pattern ‘G’ windows were more prevalent on *Olympic* than on *Titanic* because these were used for the outboard staterooms along *Olympic*’s B Deck promenade (at lower left). *Titanic* was reconfigured with B Deck deluxe staterooms which were extended out to the sides of the ship, thus eliminating the promenades and most of the inboard deckhouse bulkheads in which this window pattern was fitted, with the exception of the ones that remained within the private promenades of the Parlor Suites on B Deck (at lower right). Windows of this pattern were also installed on C Deck in the Surgeon’s, Restaurant Manager’s and Chief Steward’s quarters. *(Illustration by Jason DeDonno; images from H&W/Authors’ collection)*

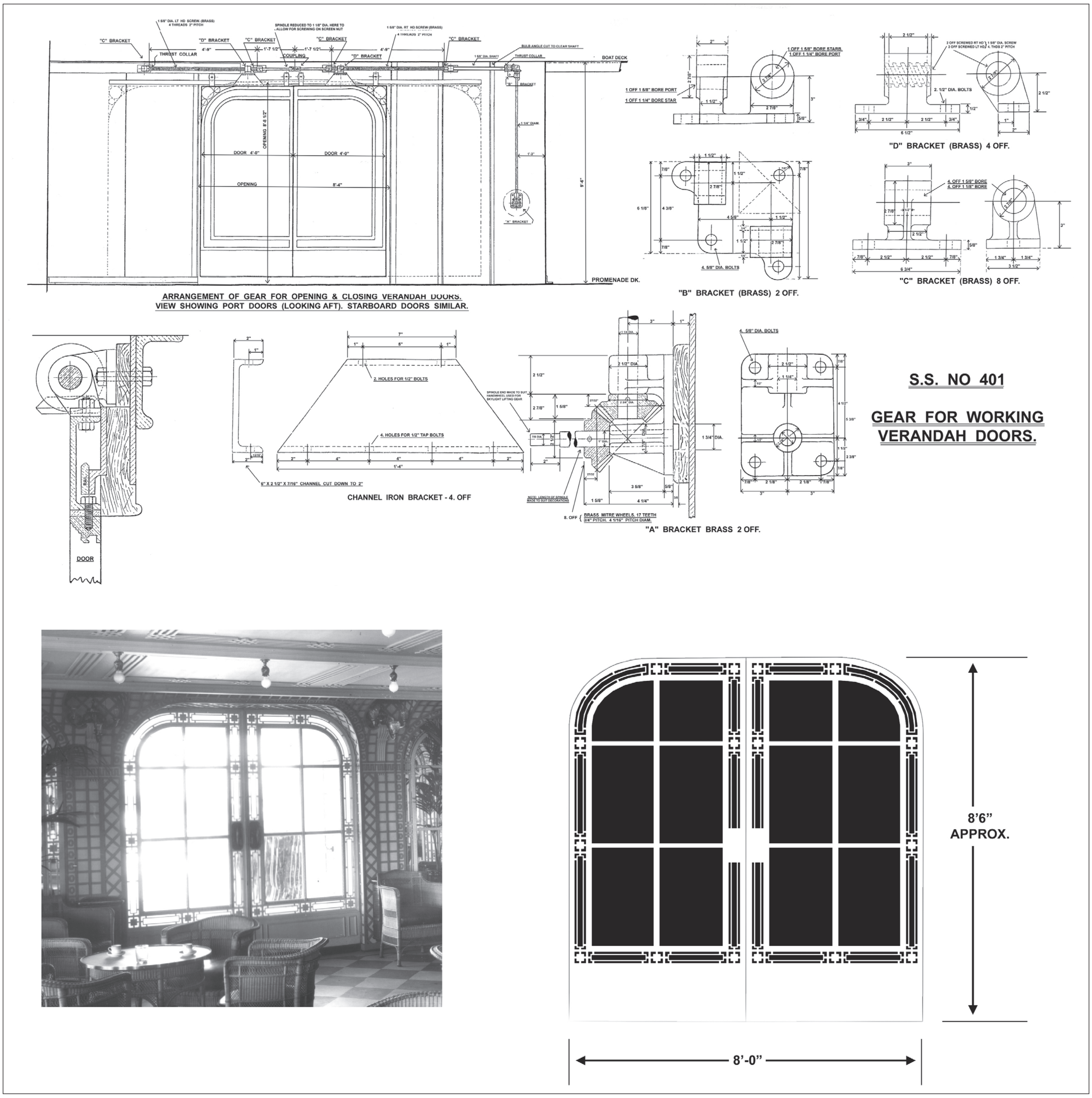

"C" BRACKET
"D" BRACKET
"C" BRACKET
"C" BRACKET
"D" BRACKET
"C" BRACKET
THRUST COLLAR
COUPLING
THRUST COLLAR
BOAT DECK
DOOR 4'-9"
OPENING 8'6 1/2"
DOOR 4'-9"
OPENING
8'-4"
"A" BRACKET
PROMENADE DK.
ARRANGEMENT OF GEAR FOR OPENING & CLOSING VERANDAH DOORS.
VIEW SHOWING PORT DOORS (LOOKING AFT). STARBOARD DOORS SIMILAR.
"B" BRACKET (BRASS) 2 OFF.
"C" BRACKET (BRASS) 8 OFF.
"D" BRACKET (BRASS) 4 OFF.
DOOR
2. HOLES FOR 1/2" BOLTS
4. HOLES FOR 1/2" TAP BOLTS
CHANNEL IRON BRACKET - 4. OFF
"A" BRACKET BRASS 2 OFF.
S.S. NO 401
GEAR FOR WORKING
VERANDAH DOORS.
8'6"
APPROX.
8'-0"

Fig. 11-23 **Verandah Doors** – The sliding glass doors of the Verandah and Palm Courts. At lower right, as they appeared from the inside. At top, a drawing of the machinery used to operate the doors. *(Lower right illustration by Jason DeDonno; image and top drawing from authors' collection)*

Skylights

Titanic was fitted with numerous skylights, varying from smaller, traditional teak-framed skylights to very large ones of steel construction. The latter category includes the skylights fitted to the hatches over the steering engines beneath the Poop Deck, the No.1 Hatch cover and the skylight atop the reciprocating engine casing.

Located on the port side of the Forecastle Deck, aft of the breakwater, was the Crew Galley skylight. Made of steel, it measured approximately 4ft x 5ft and was 2ft high at the crown. It was fitted with four round bull's-eye lights, two forward and two aft, within hinged steel flaps. The top plating was pitched to form a transverse crown at the center and was fitted with deadlights to cover the glass at night. The perimeter of the skylight's coaming was fitted with jackstays to accommodate a canvas cover.

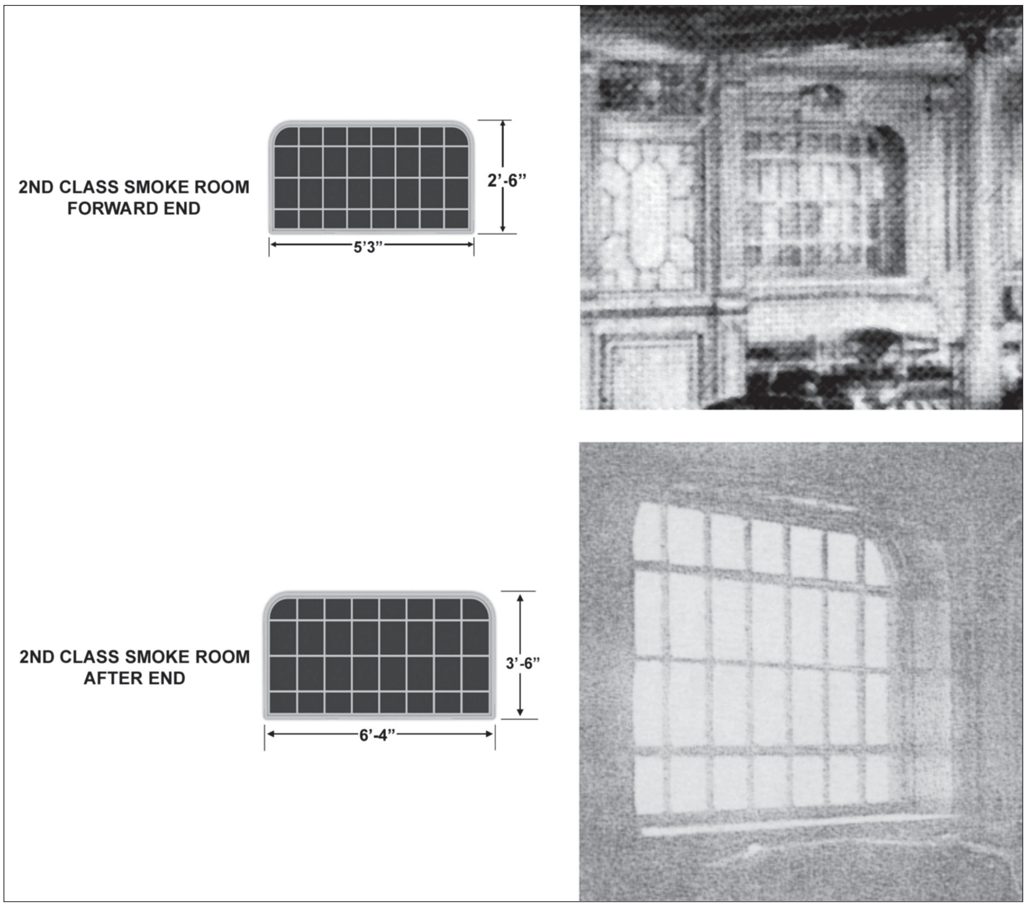

2ND CLASS SMOKE ROOM
FORWARD END
2'-6"
5'3"
2ND CLASS SMOKE ROOM
AFTER END
3'-6"
6'-4"

Fig. 11-24 **Second Class Smoke Room Windows**. *(Illustrations by Jason DeDonno; images from Daniel Klistorner collection)*

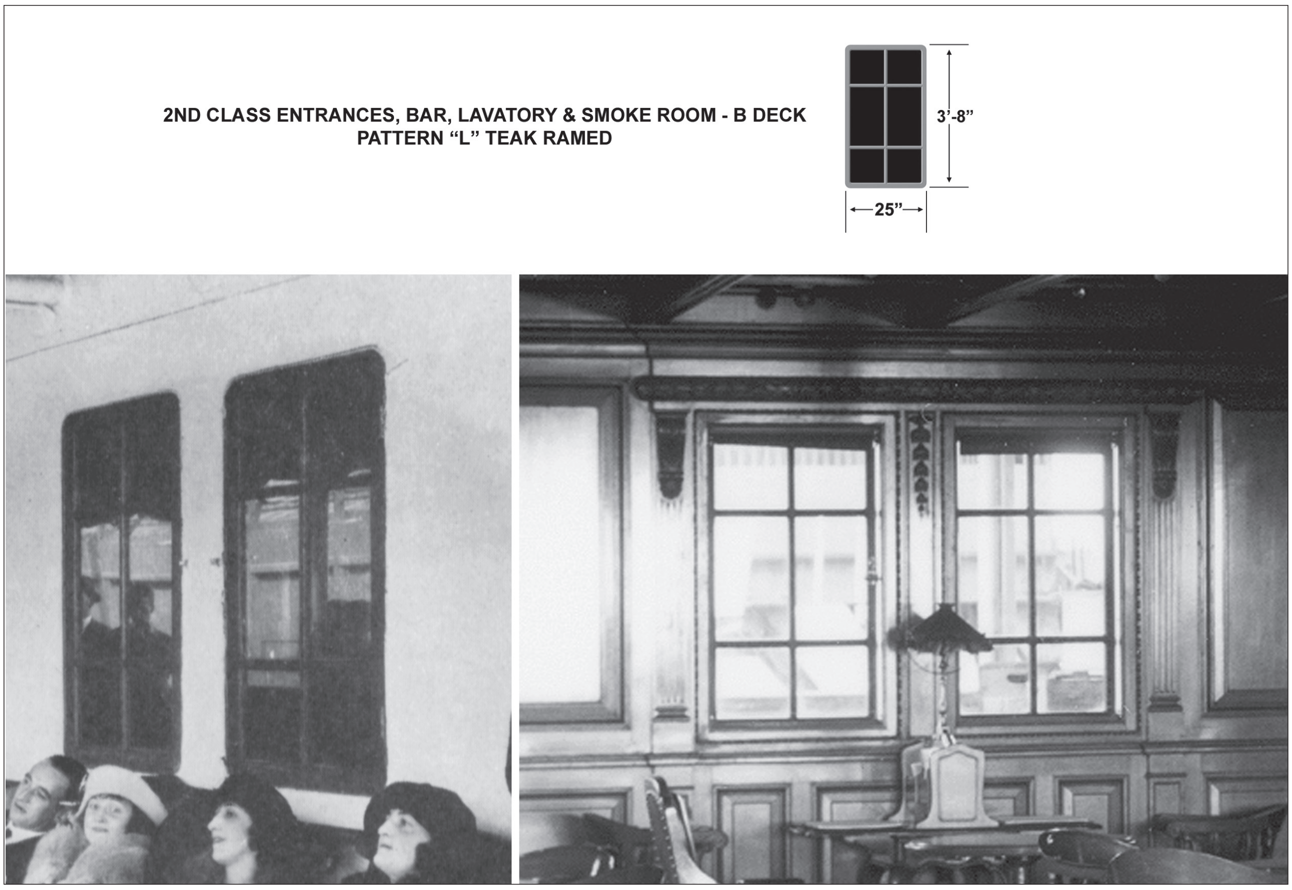

2ND CLASS ENTRANCES, BAR, LAVATORY & SMOKE ROOM - B DECK
PATTERN "L" TEAK RAMED
3'-8"
25"

Fig. 11-25 **Pattern 'L' Windows** – This image shows the pattern 'L' windows of the Second Class Smoke Room on B Deck. *(Illustration by Jason DeDonno; left image Daniel Klistorner collection; right image Craig Mestach collection)*

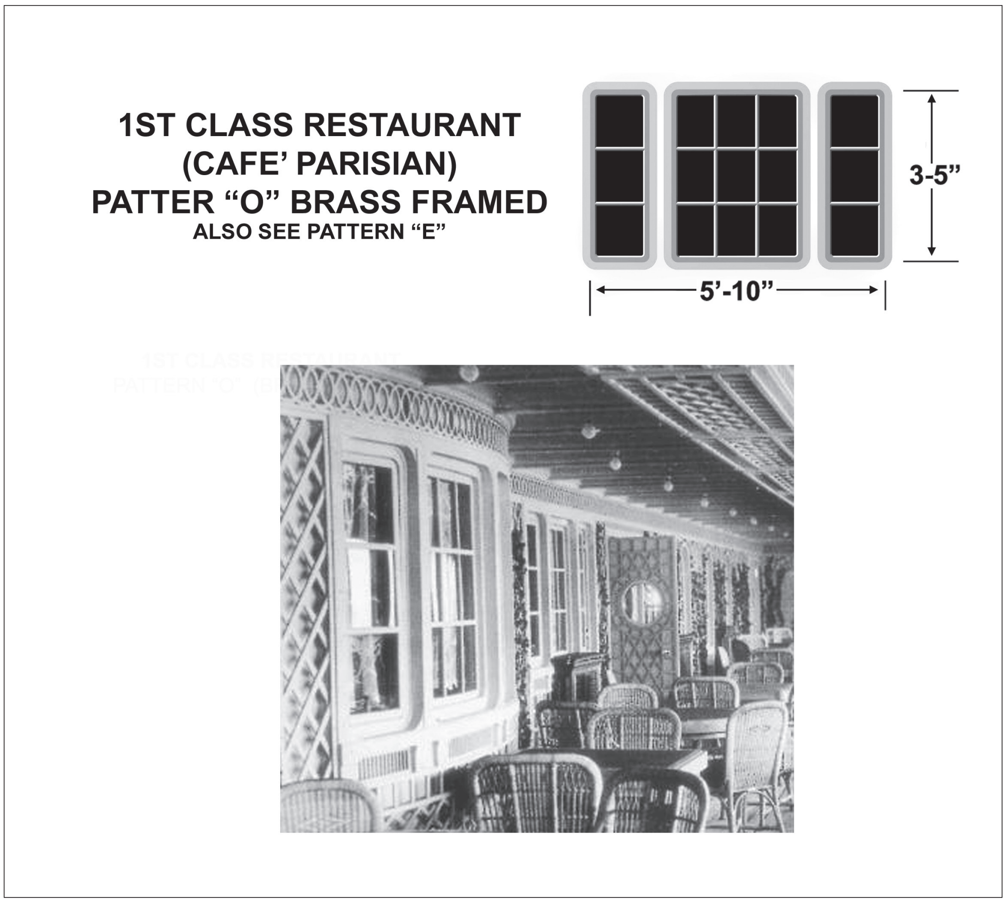

1ST CLASS RESTAURANT
(CAFE' PARISIAN)
PATTER "O" BRASS FRAMED
ALSO SEE PATTERN "E"
3-5"
5'-10"

Fig. 11-26 **Pattern 'O' Windows** – as fitted in the Café Parisien. *(illustration by Jason DeDonno; image from Daniel Klistorner collection)*

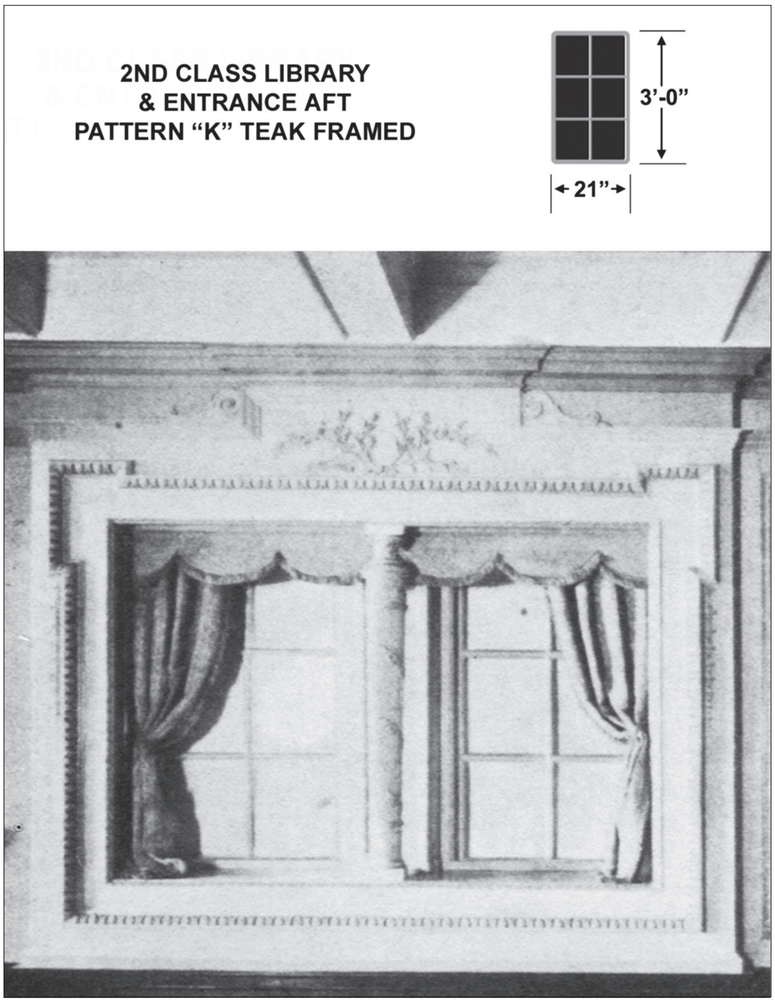
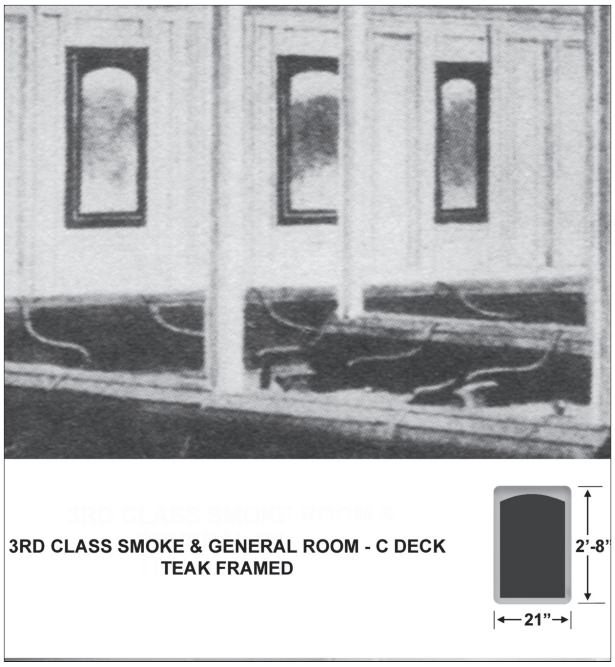

2ND CLASS LIBRARY
& ENTRANCE AFT
PATTERN "K" TEAK FRAMED
3'-0"
21"

Fig. 11-27 **Pattern 'K' Windows** – as seen here, fitted in the Second Class Library on C Deck. *(Illustration by Jason DeDonno; image from authors' collection)*


3RD CLASS SMOKE & GENERAL ROOM - C DECK
TEAK FRAMED
2'-8'
21"

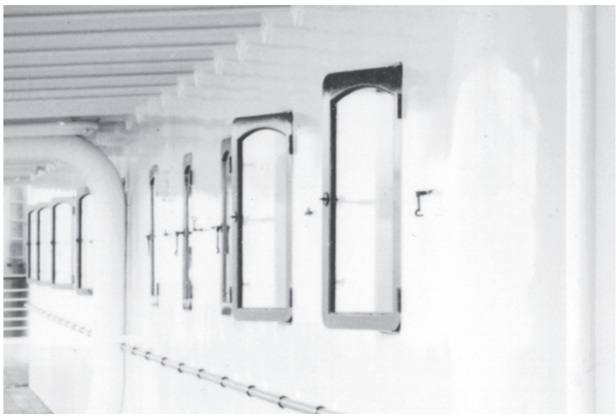


Fig. 11-28 **Third Class 'C' Deck Windows** – Left, a detail from a period artist's impression of the Third Class General Room on C Deck below the Poop Deck; this illustrates what the windows for this room and the adjacent Third Class Smoke Room looked like from the inside. Above, this image from another Harland & Wolff-built ship not of the *Olympic*-class shows how these windows on *Titanic* appeared from the outside. *(illustration by Jason DeDonno; both images from authors' collection)*

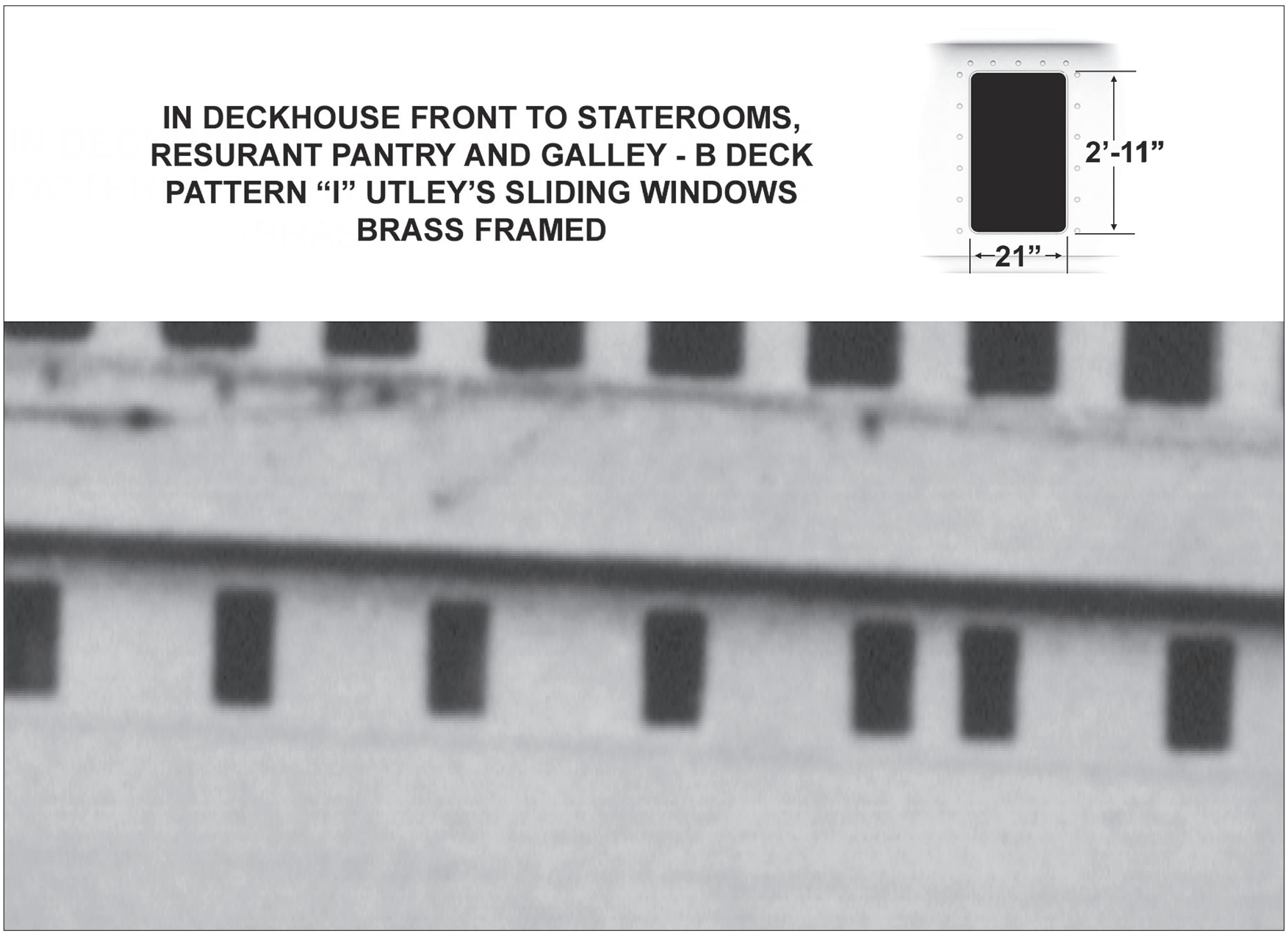

IN DECKHOUSE FRONT TO STATEROOMS,
RESURANT PANTRY AND GALLEY - B DECK
PATTERN "I" UTLEY'S SLIDING WINDOWS
BRASS FRAMED
2'-11"
21"

Fig. 11-29 **Utley's Vertical-Sliding Windows** – As shown in the image at bottom, Utley's sliding windows were used for the First Class staterooms on B Deck. Brass-framed, pattern 'I' windows measuring 35in x 21in were used in the forward end of the deckhouse, while the windows of the staterooms at the ship's side measured 32in x 19¼in. There were other variations of these used elsewhere on the ship, such as the 34in x 31in windows of the enclosed Second Class Promenade on C Deck, and the Bridge wing cabs on the Boat Deck. *Olympic*'s specifications list these last windows and the similar-but-larger windows of the Promenade Deck screens as being of Harland & Wolff manufacture, but the Utley company claims to have made them for Harland & Wolff. *(Illustration by Jason DeDonno; image from authors' collection)*

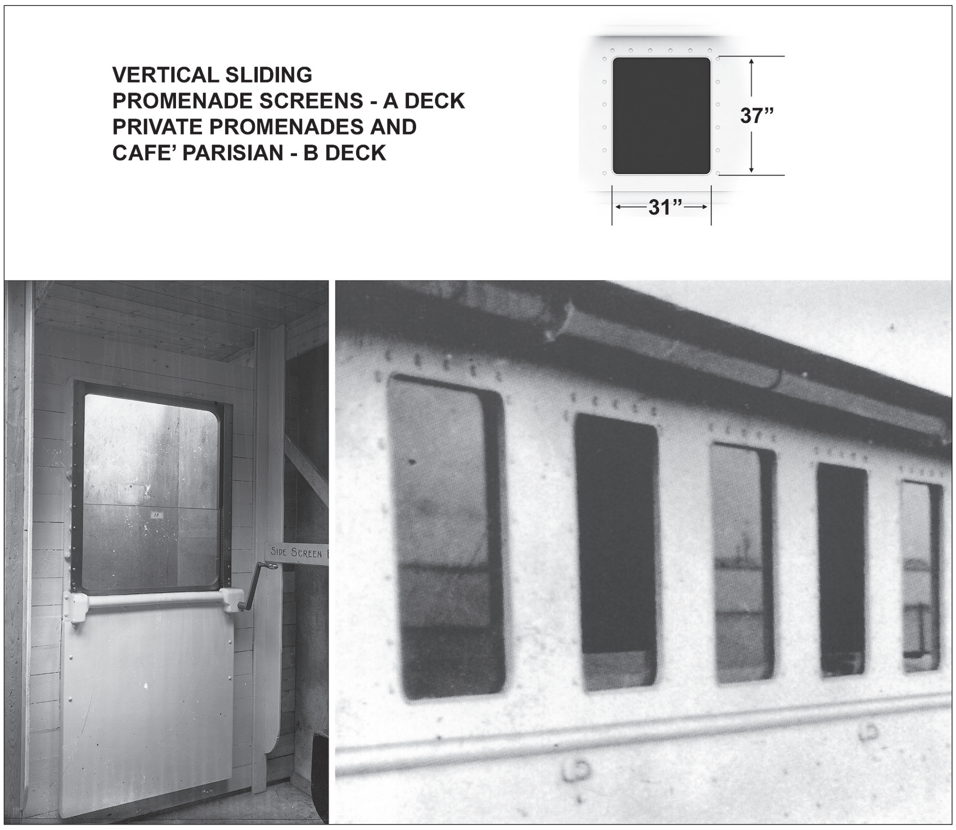


Fig. 11-30 **Vertical-Sliding Promenade Windows** – The 37in x 31in vertical-sliding windows of the A Deck promenade screens (left) and the private promenades of the Parlour Suites on B Deck (right). *(Illustration by Jason DeDonno; images from authors' collection)*

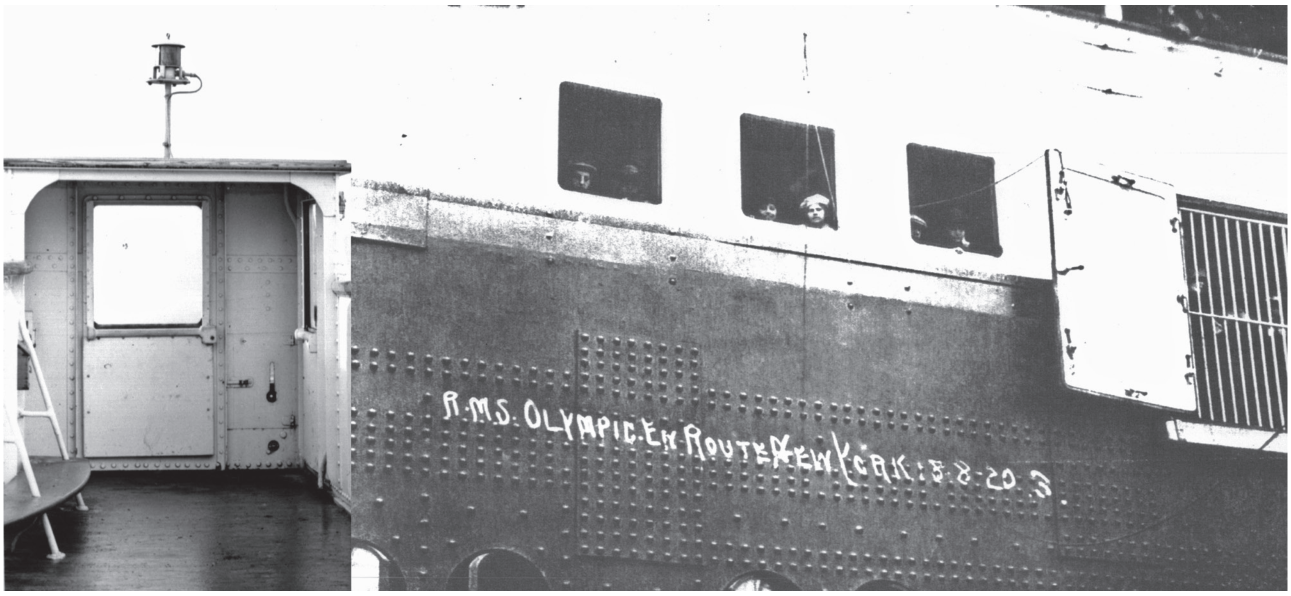


Fig. 11-31 **Vertical-Sliding Windows, Bridge Wing Cabs and Enclosed Second Class Promenade** – At left, the sliding windows of the starboard Bridge wing cab; at right, the enclosed C Deck Second Class Promenade. In this image, passengers can be seen looking out. The sills of these windows were a bit higher than most people's chins, but at some point in *Olympic*'s career, benches were installed along the sides of the promenade under the windows; the presence of these benches prompted passengers to stand on them to gain a better view, which would explain why, in this photo, the passengers' faces are in full view. *(Both images H&W/Authors' collection)*

Traditional skylights, made of teak, were fitted onto the roof of the Officers' Quarters deckhouse. One of these teakwood skylights was mounted over the Officers' Lavatory, with a matching skylight located just aft. The latter skylight was mounted over the Marconi Operating Room, slightly to starboard of the centerline, with its crown also oriented fore-and-aft. These skylights were the ordinary pitched type, having two sashes that angled up to the center like the roof of a house. The actual rise of the sashes was about 1-in-2. The center beam, called the 'crown piece', held the hinges for the port and starboard sashes; each sash contained two panes of glass.[5] Both

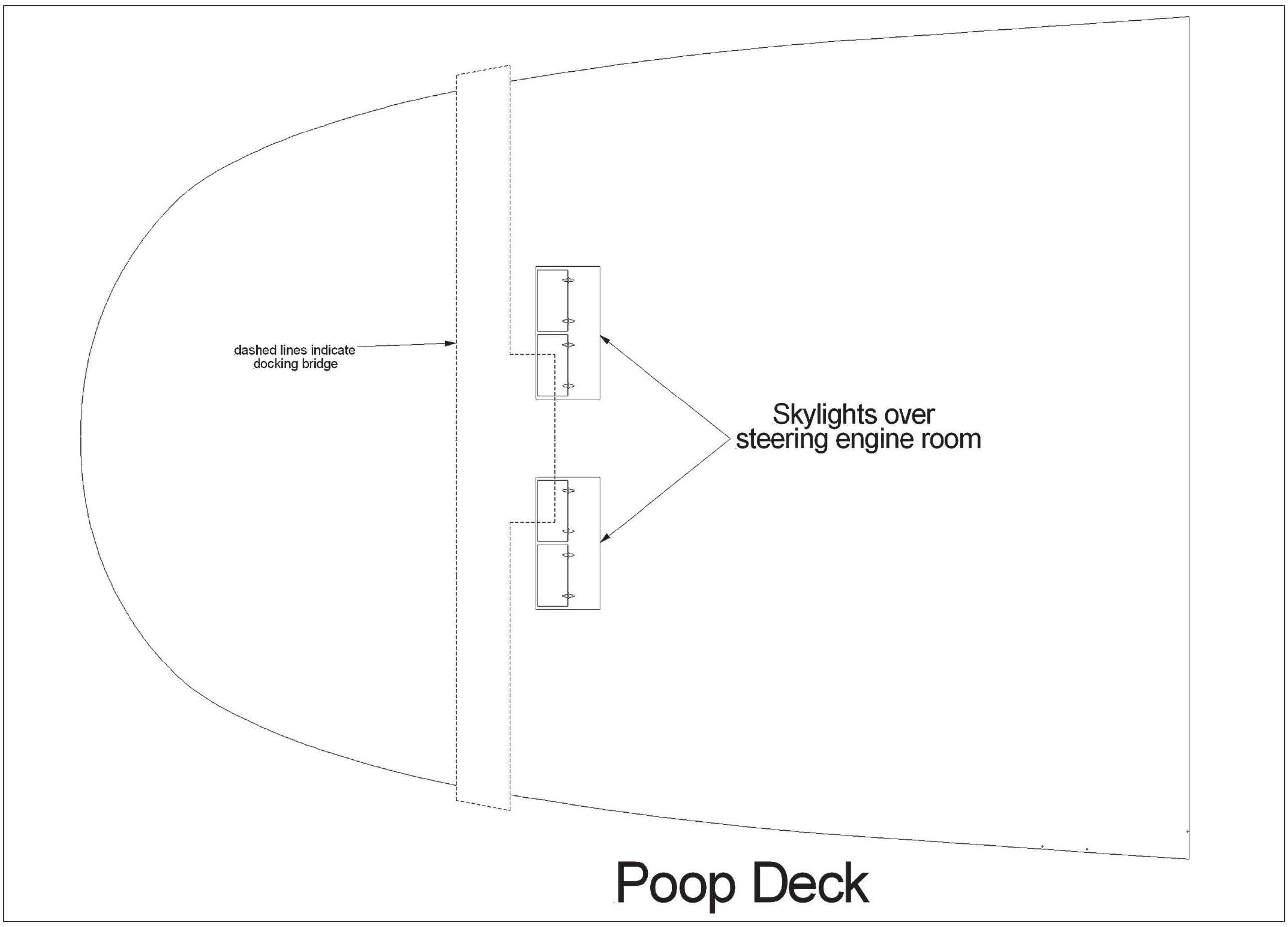
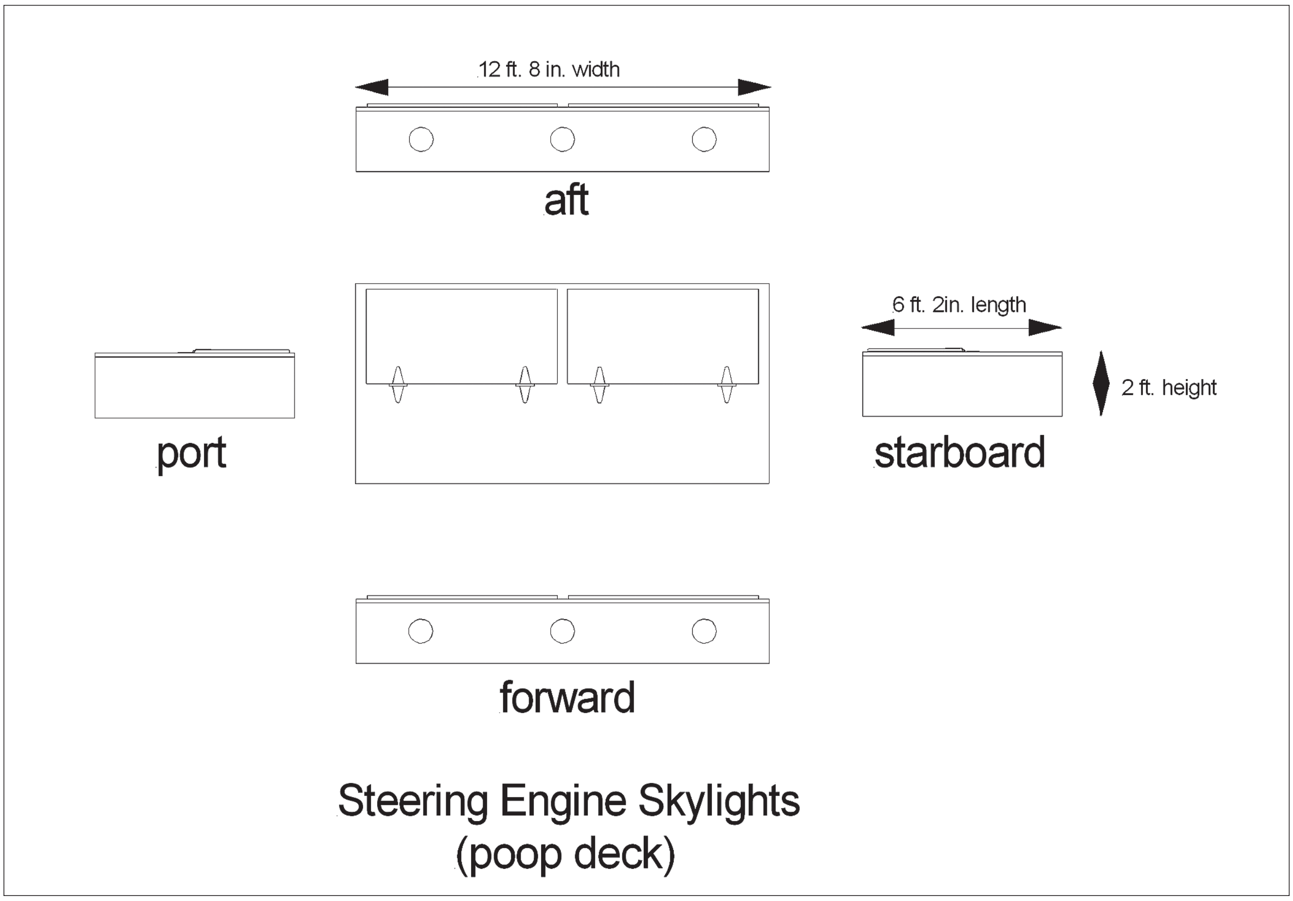
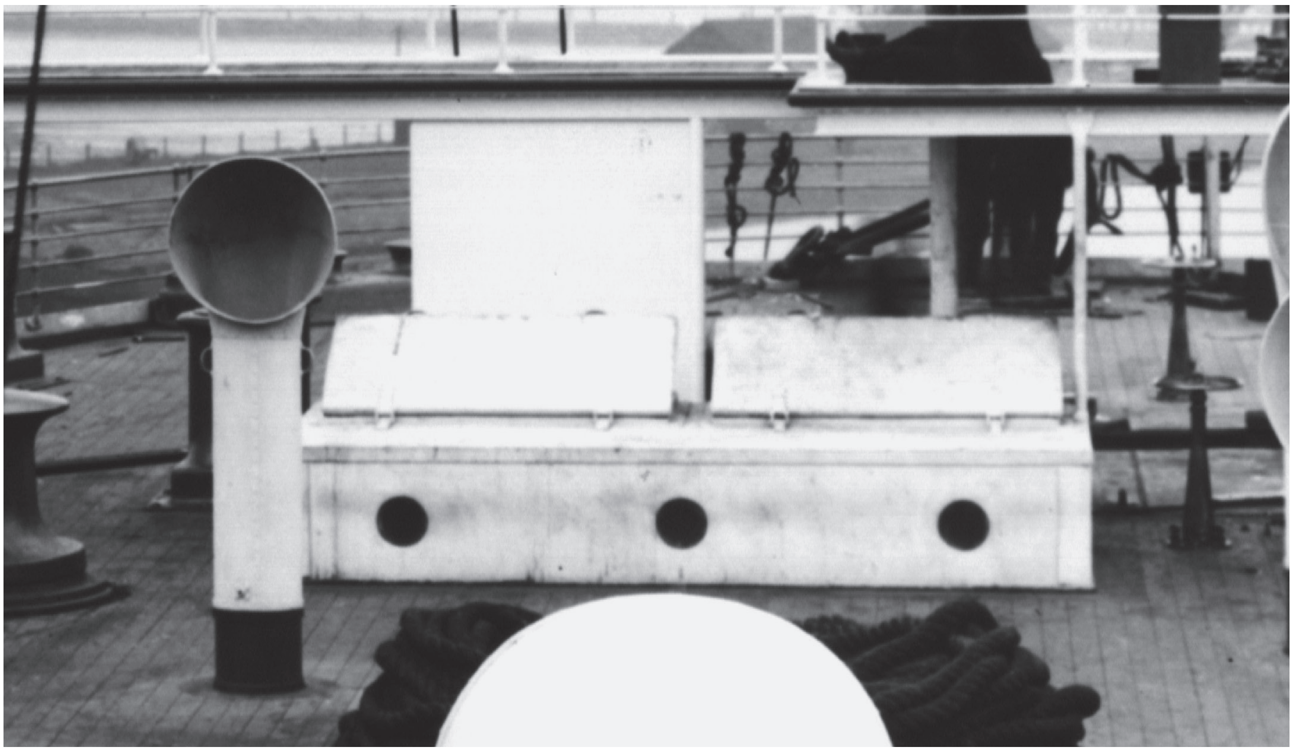

dashed lines indicate docking bridge
Skylights over steering engine room
Poop Deck

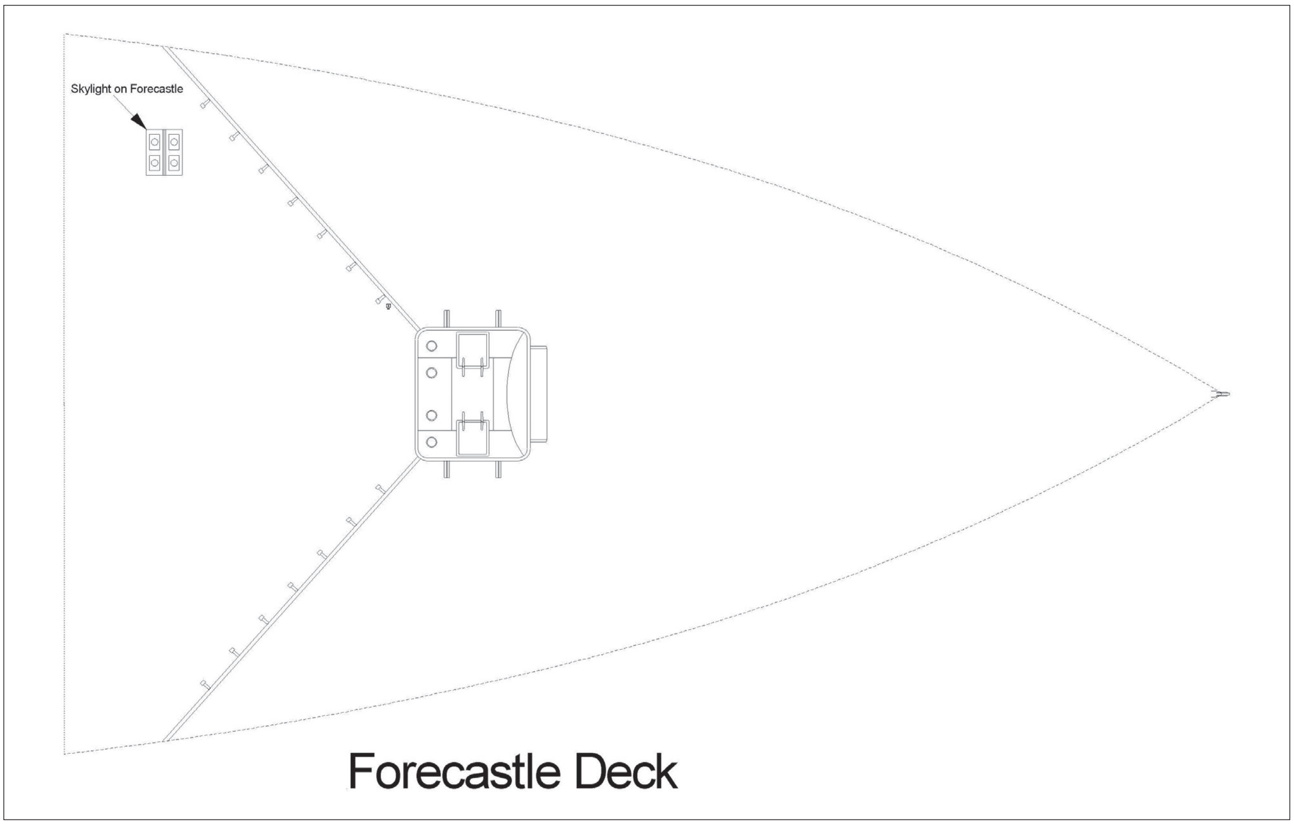
Fig. 11-32 **Skylights over Steering Engines** – The locations of the two skylights over the steering engines located below on C Deck. *(Illustration by Bob Read)*


12 ft. 8 in. width
aft
port
6 ft. 2in. length
2 ft. height
starboard
forward
Steering Engine Skylights
(poop deck)



Above Fig. 11-34 **Skylight Above Steering Engines** – This image shows the steering engine skylight on the starboard side of *Olympic*'s Poop Deck. *(H&W/Authors' collection)*

Below Fig. 11-35 **Crew Galley Skylight Location**. *(Illustration by Bob Read)*



Opposite, below Fig. 11-33 **Details of Steering Engine Skylights.** *(Illustration by Bob Read)*

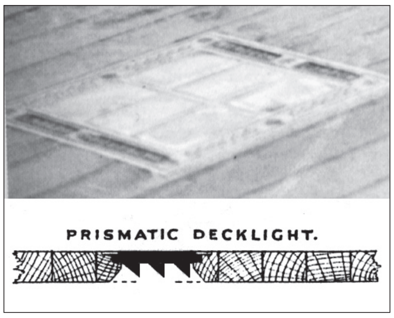

PRISMATIC DECKLIGHT.

Fig. 11-36 **Prismatic Glass Skylight** – At top, a Hayward's prismatic glass skylight as seen on the Mauretania. Below, a sectional drawing of a prismatic glass skylight fitted through the deck. *(Drawing from* Practical Shipbuilding*; image from authors' collection)*

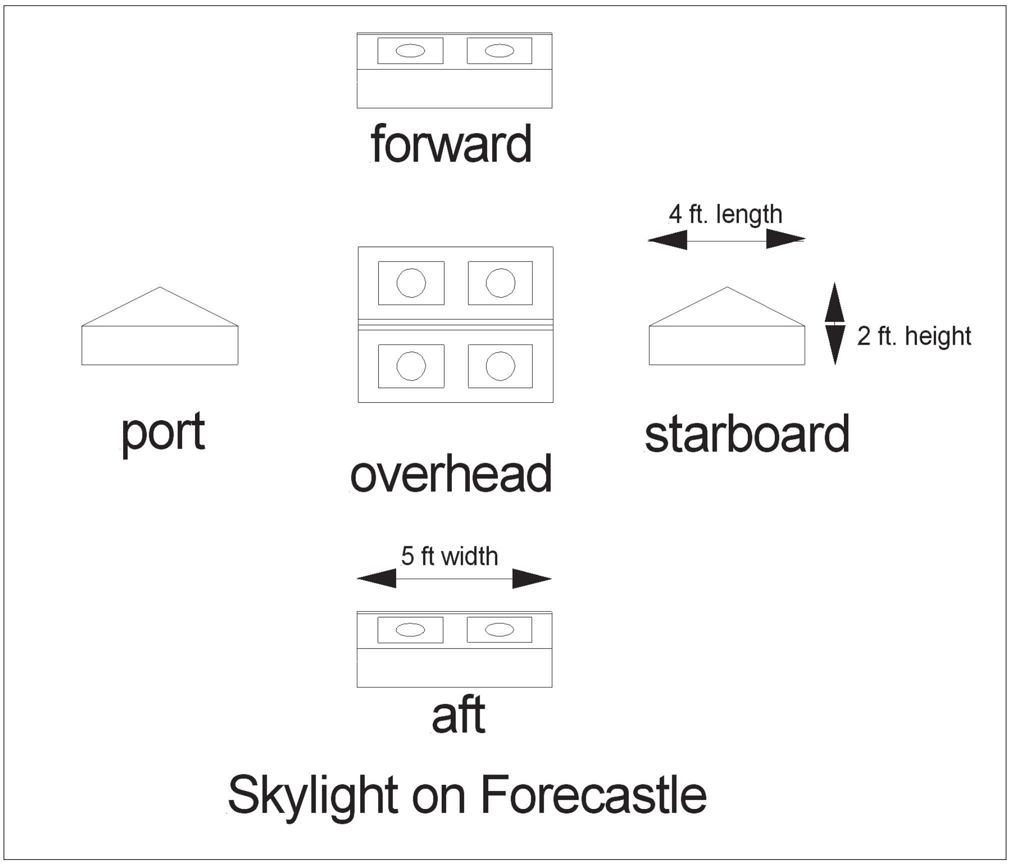

forward
4 ft. length
2 ft. height
port
starboard
overhead
5 ft width
aft
Skylight on Forecastle

Fig. 11-37 **Crew Galley Skylight**. *(Illustration by Bob Read)*

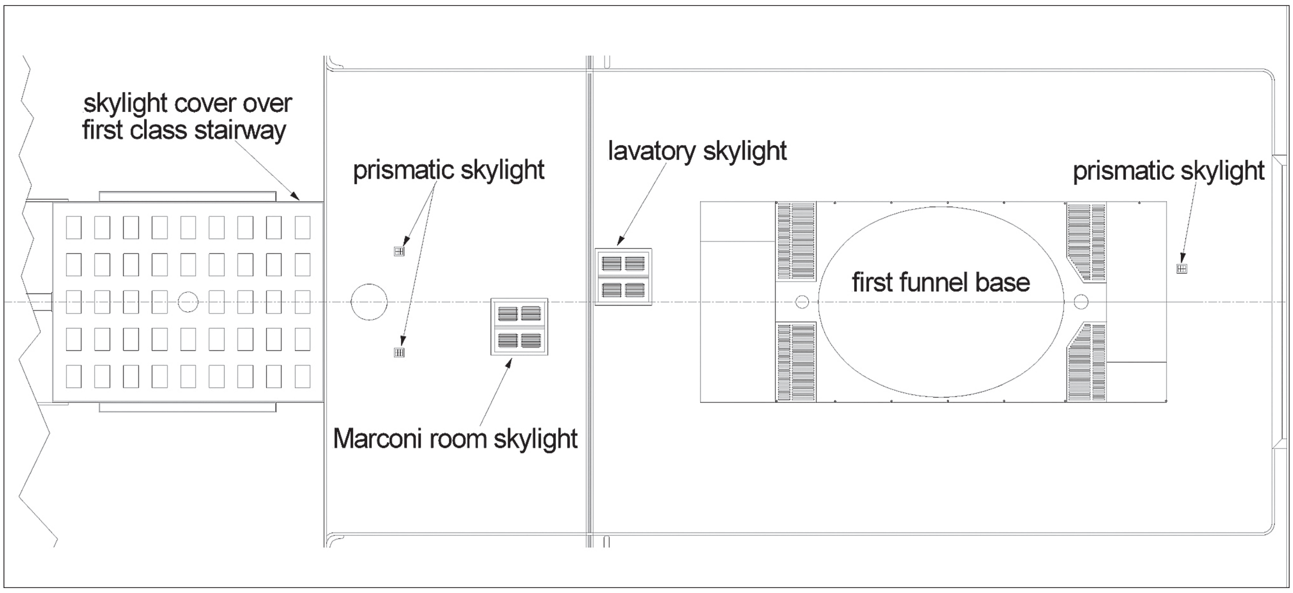

skylight cover over first class stairway
prismatic skylight
lavatory skylight
prismatic skylight
first funnel base
Marconi room skylight

Fig. 11-38 **Locations of Skylights on Roof of Officers' Quarters Deckhouse.** *(Illustration by Bob Read)*

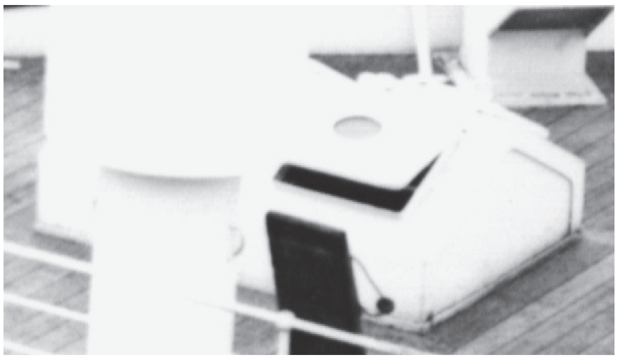


Fig. 11-39 **Crew Galley Skylight on *Olympic*** – The Crew Galley skylight as seen on *Olympic* in later years. In this image it is partially obstructed by a mushroom ventilation head that was not fitted to *Titanic*. *(H&W/Authors' collection)*

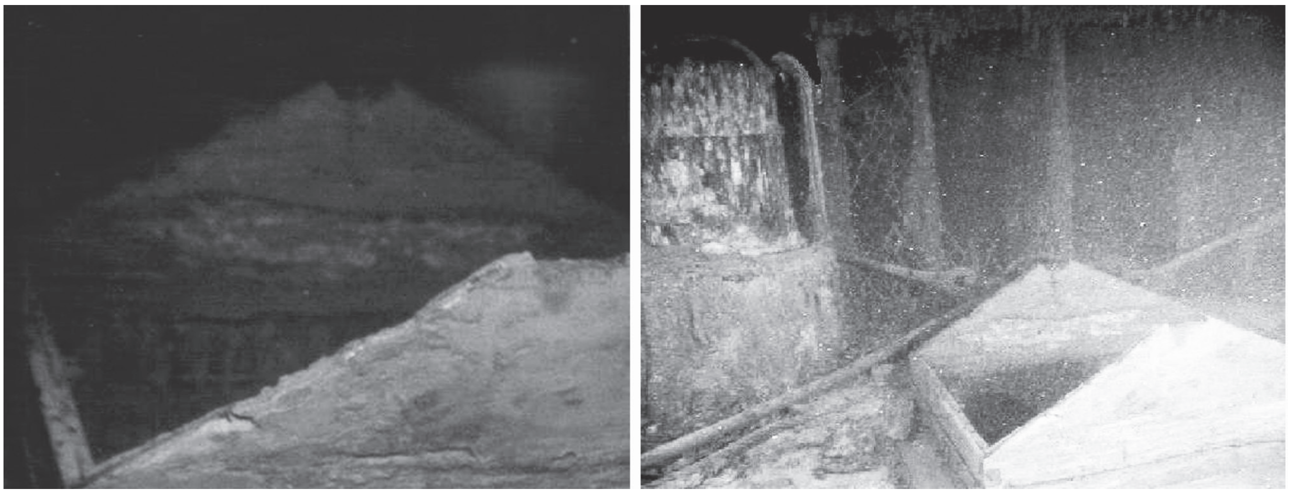
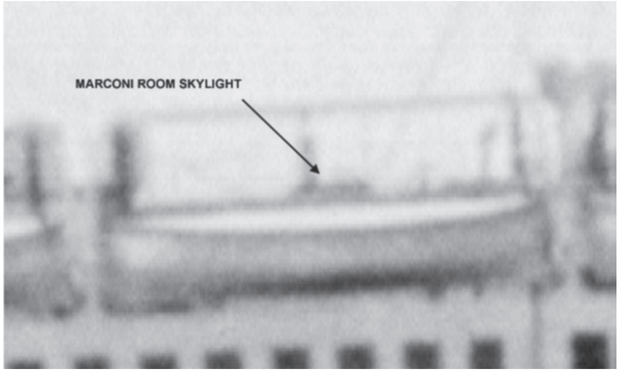


Fig. 11-40 **Officers' Lavatory Skylight on the Wreck** – The teakwood skylight over the Officers' Lavatory on the wreck of *Titanic*. At left is a close-up showing the remains of the wood. The sashes have long since disappeared. *(Steve Rigby collection)*



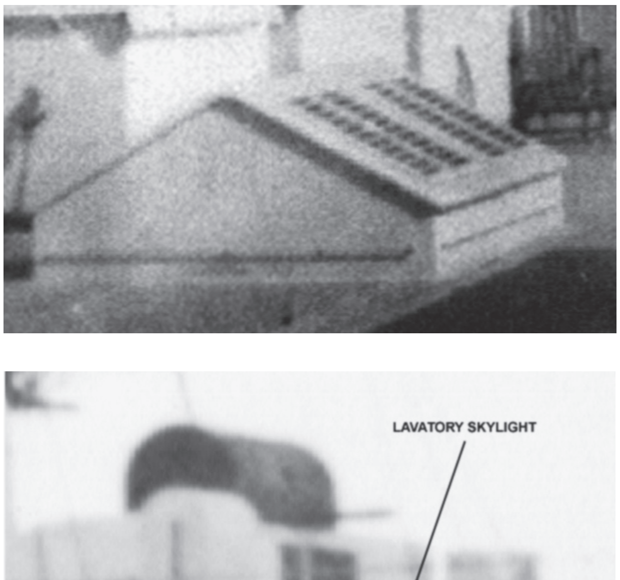


Fig. 11-41 **Titanic's Skylights** – At upper right, an example of a Harland & Wolff skylight on the raised roof of *Britannic*'s Boat Deck, port side. This skylight has two panes per side. The horizontal protection bars over the glass give the appearance of four panes per side, but this effect is caused by a central vertical strengthening bar. The upper left image is an enlarged detail of a starboard-side photograph of *Titanic*, showing the skylight over the Marconi Operating Room. At lower right, an enlarged detail of the skylight on the roof of the Officers' Quarters deckhouse over the Officers' Lavatory. This skylight, shown in the raised position, had two sashes per side. *(*Britannic *photograph courtesy Simon Mills; others from authors' collection)*

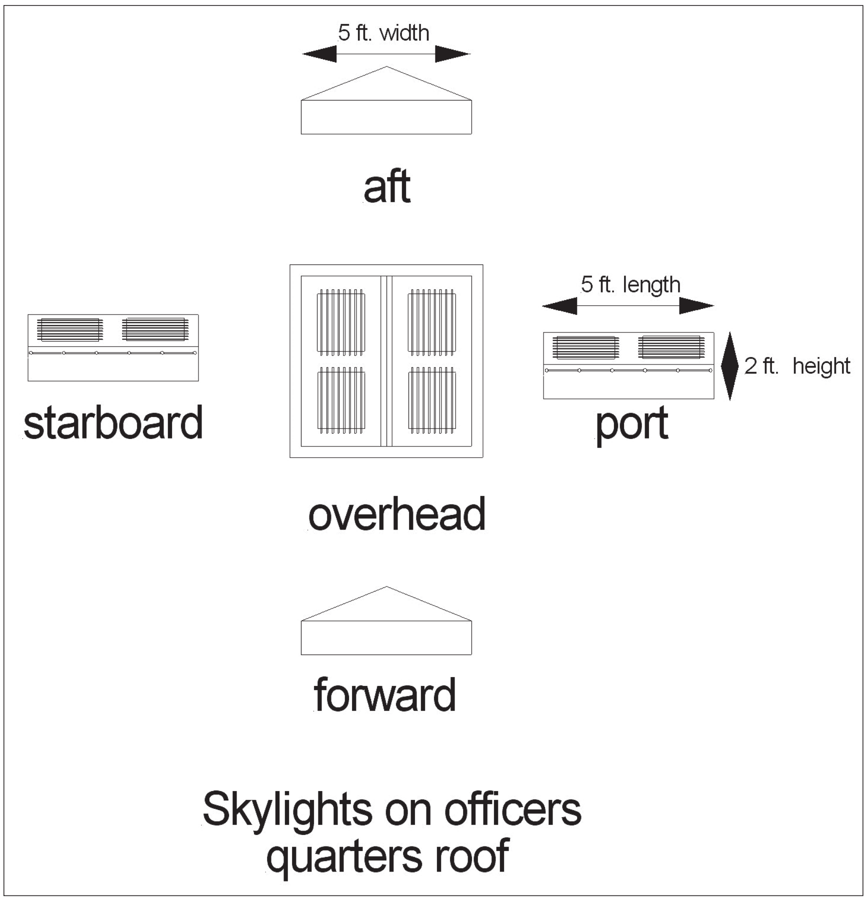

5 ft. width
aft
5 ft. length
2 ft. height
starboard
port
overhead
forward
Skylights on officers quarters roof

Fig. 11-42 **Teakwood Skylight** – Drawing of a skylight typical of those installed on the roof of the Officers' Quarters deckhouse. *(Illustration by Bob Read)*

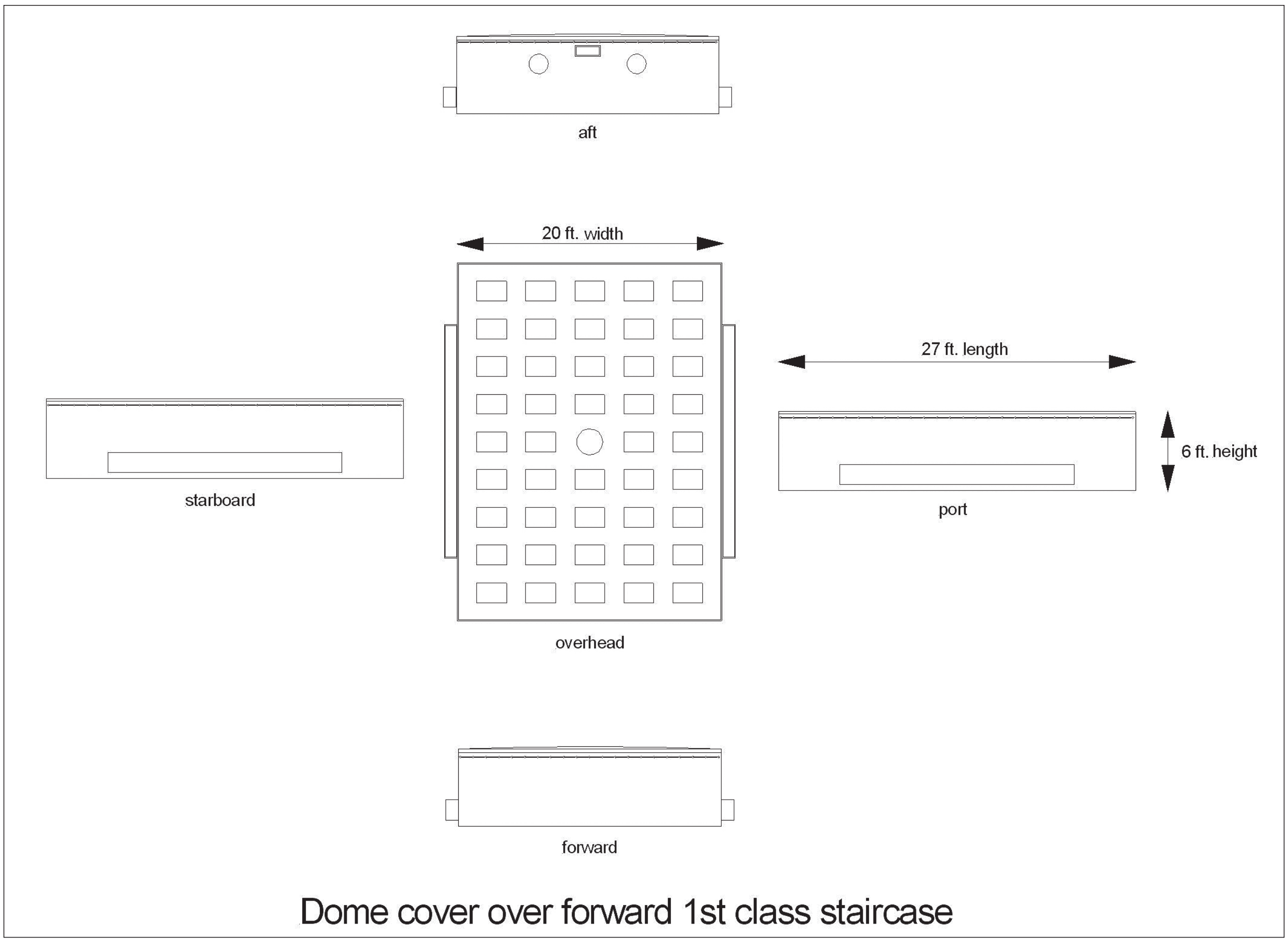

aft
20 ft. width
27 ft. length
6 ft. height
starboard
port
overhead
forward
Dome cover over forward 1st class staircase

Fig. 11-43 **Dome Cover over Forward First Class Staircase.** *(Illustration by Bob Read)*

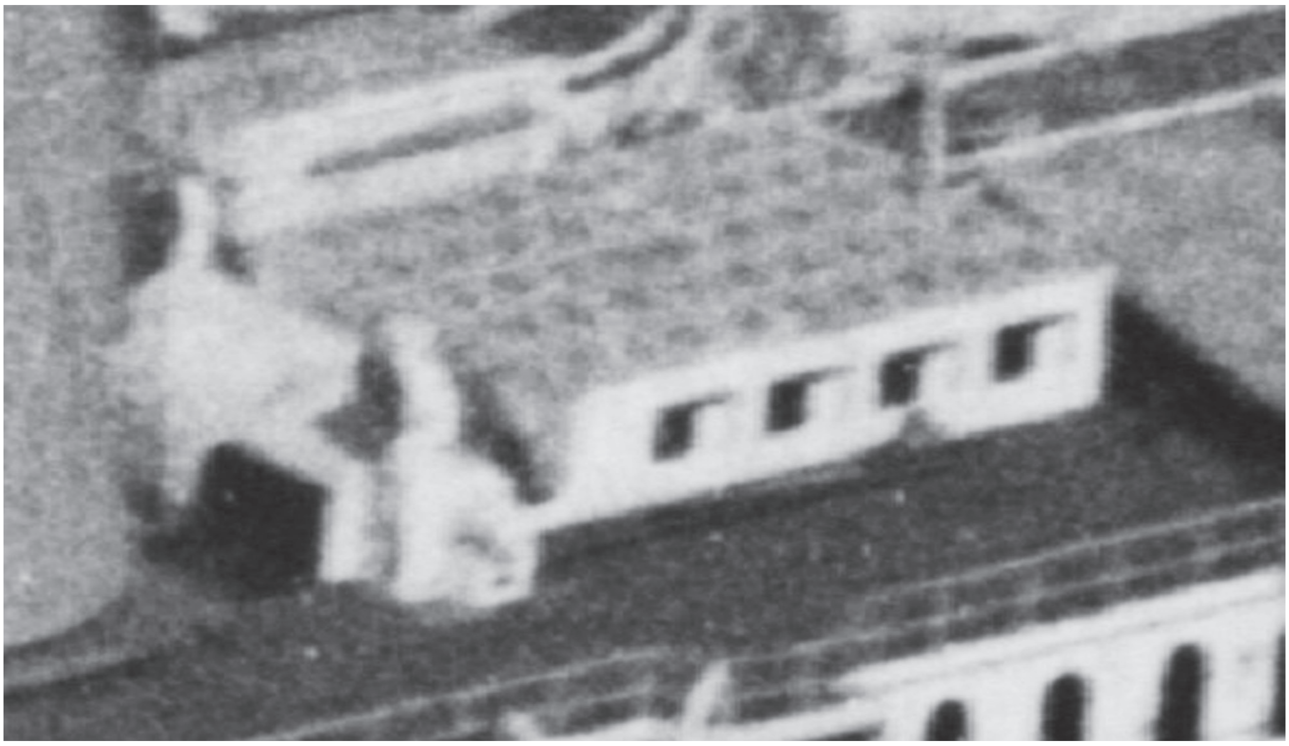


Fig. 11-44 **Dome Cover over Forward First Class Staircase on *Olympic*** – The dome cover over the forward First Class staircase on *Olympic*, as photographed in 1923. The sidelight covers on the coaming, seen here as dark boxes, were unique to *Olympic*. *Titanic* did not have these sidelights in the port and starboard coamings of the cover but did have two bull's-eye lights in the after coaming.

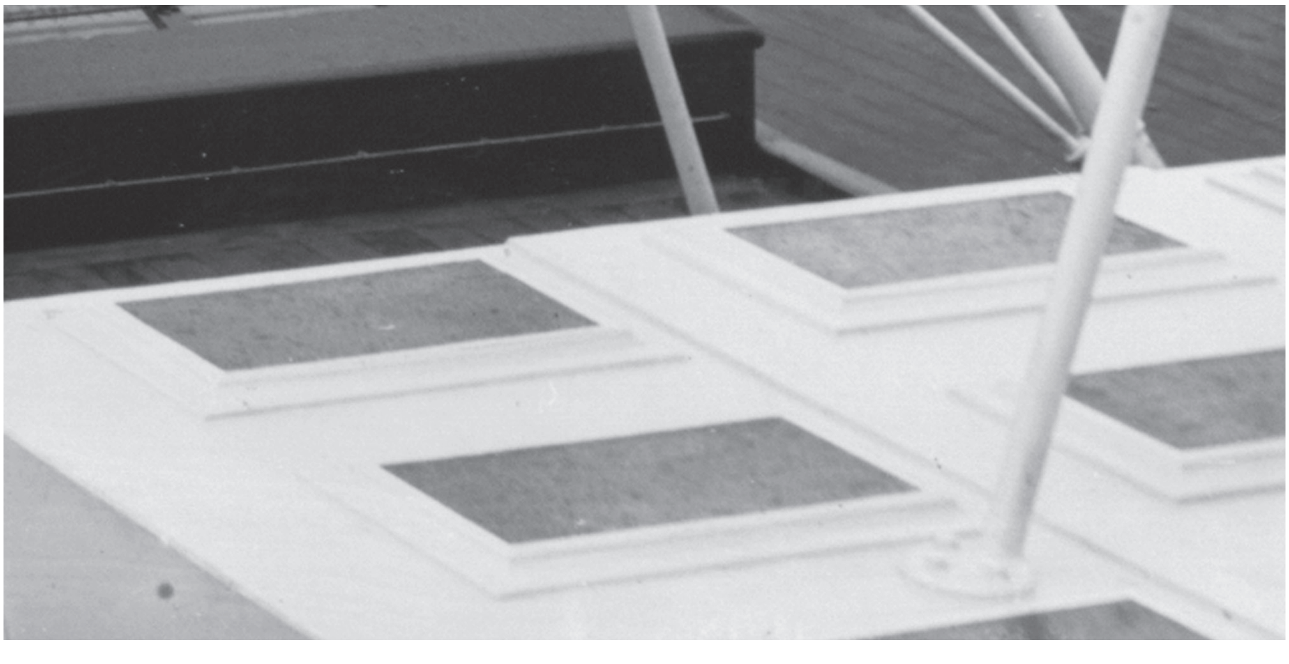


Fig. 11-45 **Dome Cover Skylight** – A close-up detail of the rectangular lights in a dome cover skylight from a Harland & Wolff-built ship of the same period as *Titanic*. *(H&W/Authors' collection)*

skylights stood 2ft off the deck at the crowns, which were oriented fore-and-aft. The outside dimensions of both skylights were 5ft x 5ft, with 6in-high coamings.

In a traditional teakwood skylight, the glass was set into the teak sashes so that they could be raised and lowered internally by the use of a quadrant operated by a wheel and screw. Because these skylights were in exposed positions, with the glass at risk of damage from the elements, falling ice or other hazards, they were fitted with protective bars or barred frames that covered the glass panes; this type of protection was typical for skylights mounted on weather decks. These bars, of brass or galvanized iron, were set at about 2in centers, with the sashes rabbeted on the upper side to receive the barred frames. The frames were portable and were held in position by bolts and wing nuts. The coamings of the skylights were also fitted with jackstays to secure fitted canvas covers.

For locations where a traditional skylight would obstruct a deck surface or roof area subject to frequent foot traffic, prismatic skylights could be employed. These had the advantage that they could be mounted within and completely flush to a deck or roof surface, and could be walked on if necessary. The prismatic skylights on *Titanic* were of Hayward's Borough Patent design, with a brass frame containing rows of prismatic glass blocks tightly fitted to disperse the rays of light passing through it. Prismatic skylights were fitted in several locations on *Titanic*, including two on the Officers' Quarters deckhouse roof over the Elevator Machinery Room – one on each side of the centerline – and one above the Chart Room forward of the No.6 Boiler Room stokehold vent.

Two of the more prominent features aboard *Titanic* were the large skylight domes above the First Class staircases fore and aft; both of these domes were enclosed by protective covers above, fitted with skylights on top to admit light to the domes below. The dome cover over the forward First Class staircase was located on the top of the Officers' Quarters deckhouse (this deck area was sometimes termed the 'Sun Deck').

The dome cover at this location was built of steel plating, measured approximately 27ft x 20ft, and was situated between frames 31F and 40F. The skylight consisted of a cambered lattice top containing forty-four rectangular glass lights, each measuring 27in x 18in. The glass of these lights was dulled to allow an even dispersion of light onto the dome below, thereby eliminating the shadows which would have otherwise resulted from the lattice construction of the skylight. Located in the center of the dome cover was a round convex light approximately 12in in diameter. Jackstays were mounted along the upper edges of the forward dome cover's plating to secure canvas covers when required.

Two bull's-eye lights were mounted in the after coaming of this skylight cover, one to port and one to starboard. A ventilation duct was fitted on the after side of the coaming; this duct exited the structure near the top, after which it was run down and then aft along the top of the wood deck to the base of the No.4 Boiler Room stokehold duct. This ventilation ducting would have been installed to minimize the formation of condensation on the inside of the dome cover.

The cover over the dome above the after First Class staircase was of the same design as its forward counterpart. It was situated on the Boat Deck proper (rather than on a deckhouse roof) between frames 39A and 46A, with the forward coaming of the cover formed by the after bulkhead of the light-and-air shaft within the reciprocating engine casing. The dome cover at this location was slightly smaller than the forward one, measuring approximately 21ft x 20ft. The rectangular skylight was of the same construction as the forward one; the rectangular lights on top numbered 34 and measured 27in x 18in each. As with the forward dome cover skylight, the center was fitted with a round convex light approximately 12in in diameter. There were no jackstays fitted around the perimeter at the top edge of this cover as there were with the forward one.

Located on the Poop Deck, just forward of the Docking Bridge, were two raised, white-painted steel skylights. Situated one on each side of the Poop Deck over the steering engines, these were built of strong steel coamings which formed rectangular boxes. On the top of each of these skylights were two windowless, watertight flaps, the primary purpose of these being to provide ventilation rather than light, and also to provide access to the steering engines from the open deck above during overhaul and servicing. In order to admit some natural light into the steering gear compartment when the flaps were dogged closed, sidelights were fitted in the forward and after coamings of each skylight.

A skylight was also situated over the reciprocating engine casing at roof level with the surrounding deckhouse that contained the Tank Rooms and the Engineers' Smoke Room. This skylight was built of steel and fitted with steel flaps, four to port and four to starboard, having four bull's-eye lights each. The flaps were opened and closed remotely by rack-and-pinion gearing through an arrangement of shafts and handwheels. The plating between two of the flaps on each side (port and starboard) was made portable in order that equipment could be hoisted up or lowered through the casing[6] from the Engine Room by means of a dockside crane.

The Reciprocating Engine Room skylight was also an integral part of the ventilation for the Engine Room, as it served to exhaust the heated air rising up from below. Because of this, the skylight flaps are almost always seen opened when the ship is in service.

Skidlights

A skidlight is a sidelight mounted low down on a bulkhead, at or near deck level. Round skidlights were furnished along the deck level of the Officers' Quarters deckhouse to provide natural light and air to the inside staterooms below on A Deck. Utilizing prismatic glass, light would enter through angled shafts to the deckhead

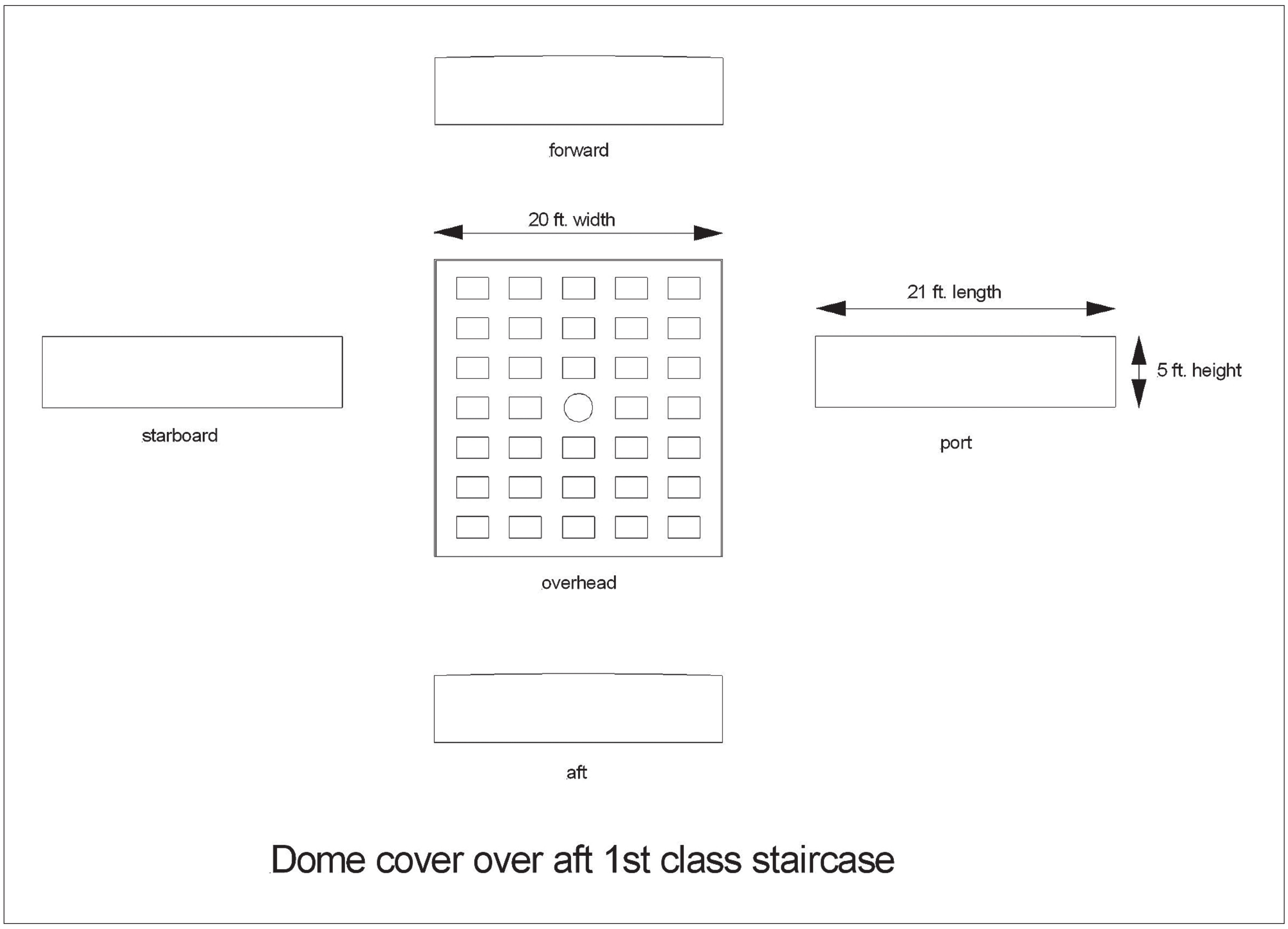

forward
20 ft. width
21 ft. length
5 ft. height
starboard
port
overhead
aft
Dome cover over aft 1st class staircase

Fig. 11-46 **Dome Cover Over After First Class Staircase.** *(Illustration by Bob Read)*

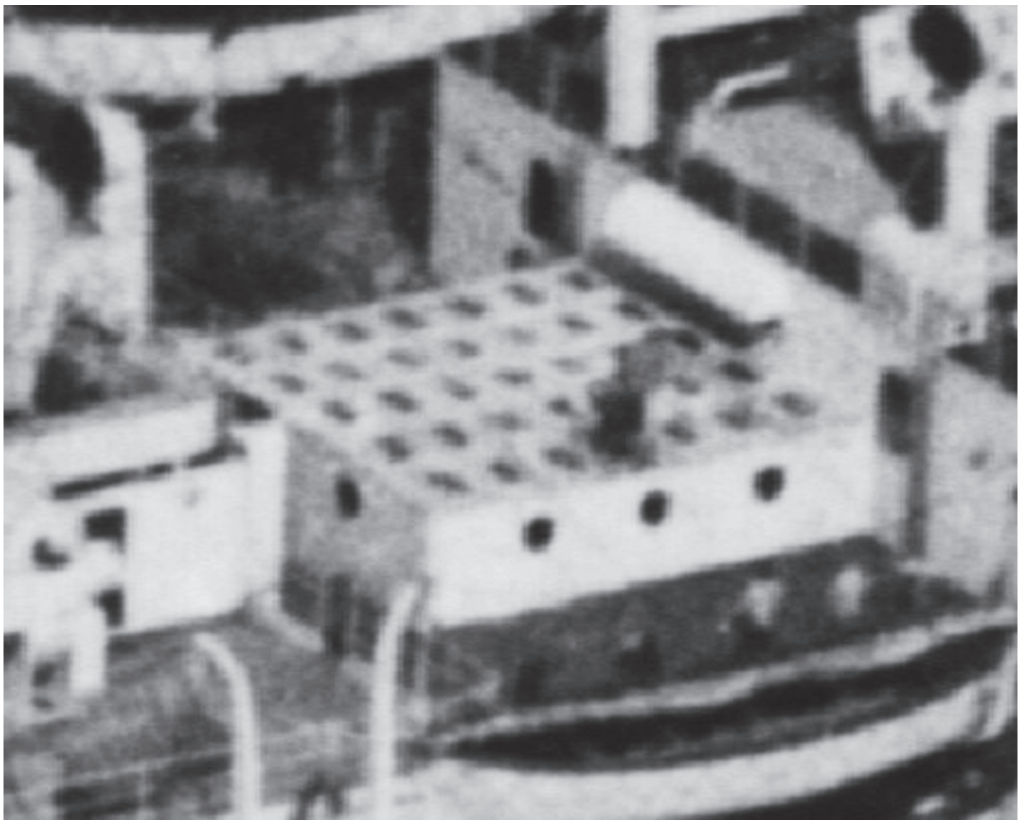


Fig. 11-47 **Dome Cover Over After First Class Staircase on *Olympic*** – This image shows the dome cover over the after First Class staircase on *Olympic*, also photographed in 1923. As with the forward cover, *Titanic* did not have the bull's-eye lights on the port and starboard sides of the coaming. This photograph shows the two lights in the after coaming that *Titanic* may have had, but their presence can not be verified as of this writing.

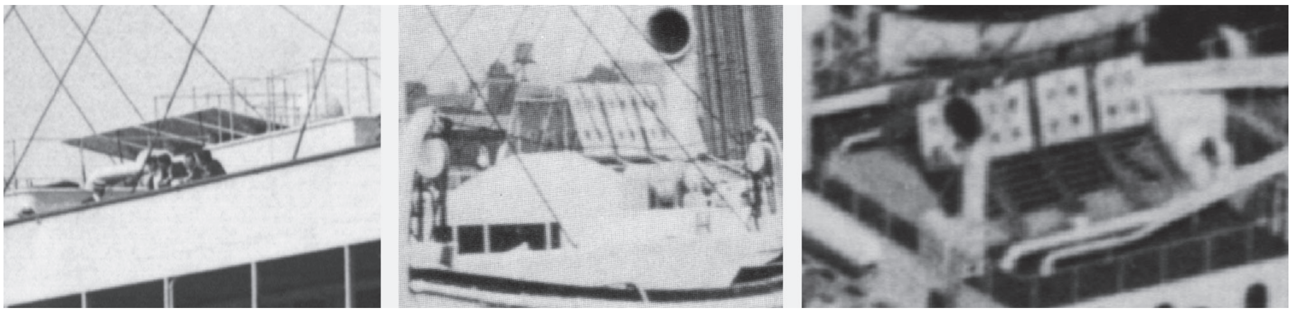
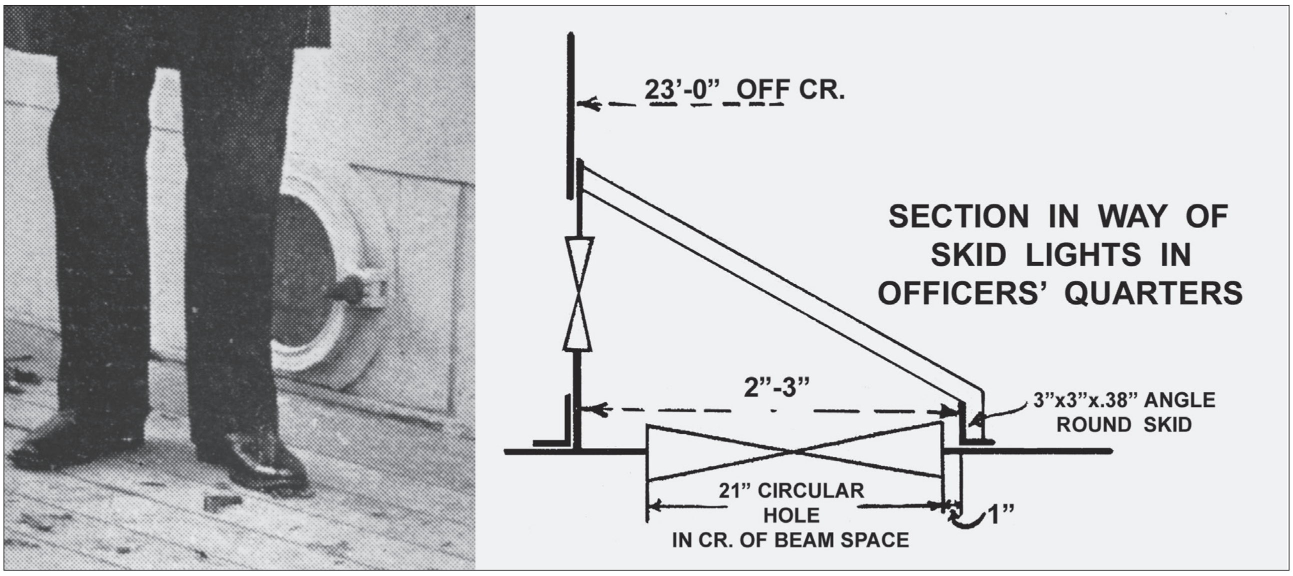


Fig. 11-48 **Skylight Over Reciprocating Engine Casing** – Three views of *Olympic*'s reciprocating engine casing skylight from different times in her career. The same design was used on *Titanic*. *(All images authors' collection)*



23'-0" OFF CR.
SECTION IN WAY OF SKID LIGHTS IN OFFICERS' QUARTERS
2"-3"
3"x3"x.38" ANGLE ROUND SKID
21" CIRCULAR HOLE IN CR. OF BEAM SPACE
1"

Fig. 11-49 **Section in Way of Skid Lights** – A section through the Boat Deck in way of the skid lights fitted in the coaming plates of the Officer's Quarters deckhouse. At left, a detail from an image of Captain Smith on the Boat Deck of *Titanic*. *(Image from authors' collection; illustration by author based on original H&W plan)*

below, the trunked shafts being hidden within the Officers' Quarters behind furniture. These are covered in more detail in Chapter 5 of Volume 2.

Notes

1. A fixed (non-opening) round window located in a door, bulkhead or in the hull was commonly called a 'bull's-eye light.' The term 'light' refers to a pane of glass used to admit natural light to the space within.
2. These external plugs do not appear to be of the same design as those provided for the sides of the hull. It is unclear how they were mounted, but the sidelights in this area, some being of the Utley's pivoting type, did not have projecting lips as did the ones in the hull.
3. On *Titanic,* this was E Deck.
4. T. M. Utley Offshore, Plc did not provide the author with copies of this document, so it cannot be verified whether their statements are accurate. The original builder's plans do indicate that Utley's brass framed 'French' windows were used for the First Class staterooms at the forward end of the A Deckhouse.
5. General Arrangement plans of *Britannic* show three panes per side on each of the two Officer's Quarters deckhouse skylights. However, an enlargement of a photograph of *Titanic* indicates two panes per side. This configuration is consistent with photographs of other skylights of generally the same size on other White Star Line ships, specifically, *Britannic*'s raised roof on her Boat Deck.
6. This area of the ship is covered in more detail in Chapter 9 of this volume.

Chapter 12

Bulwarks, Railings and Awnings

Bulwarks

On steel vessels, solid bulwarks were fitted to many areas along the outer perimeters of the weather decks for the safety of the passengers and crew. The bulwarks were usually formed from thin steel plates which, although of lighter materials and not a component part of the hull proper, were substantially stiffened and braced from behind in order to endure the severe stresses placed upon them by the repeated impact of green seas in heavy weather.

The bulwark plating was generally .20in- to .44in-thick, with the lighter plating employed on the higher decks to save weight and thereby minimize any negative effect on the ship's stability. The plates were formed in lengths varying from 12 to 20ft and were joined together with single rows of rivets. Depending on the location of the bulwark, the plating was connected to either the upper edge of a sheer strake or to a curtain plate by a double row of rivets along its lower edge. Due to the thinness of the material from which the bulwarks were constructed, stiffening of the upper edge of the plating was required. This was accomplished by fitting sections of bar iron rolled specifically for this purpose, or by mounting handrails to the top of a length of bulb angle riveted along the inboard top edge of the bulwark. The bulwark plates were further braced with vertical angle stiffeners riveted to the inboard side of the plating, typically at 3ft intervals.

The bulwark plating also required some form of support from the deck. This was provided by specially forged round iron stays. The bulwark stays were generally 1½in in diameter and located at about 6ft intervals, or at every other vertical stiffener. The upper end of these stays were formed into a flattened 'palm' by which they were attached to the upper end of the angle stiffeners, while the lower end had a specially formed 'foot' through which a two-rivet connection was made to the deck plating. In cases where the stays were not bolted to the deck plating, they were riveted to an inboard angle of the adjacent waterway. Stays were installed at all athwartship bulwarks and, for short distances, at the fore and aft ends of the A and B Deck promenade bulwarks. Further support was given to the port and starboard bulwarks of A and B Decks by attaching these to the vertical frames that supported the outboard ends of the transverse beams of the deck directly above.

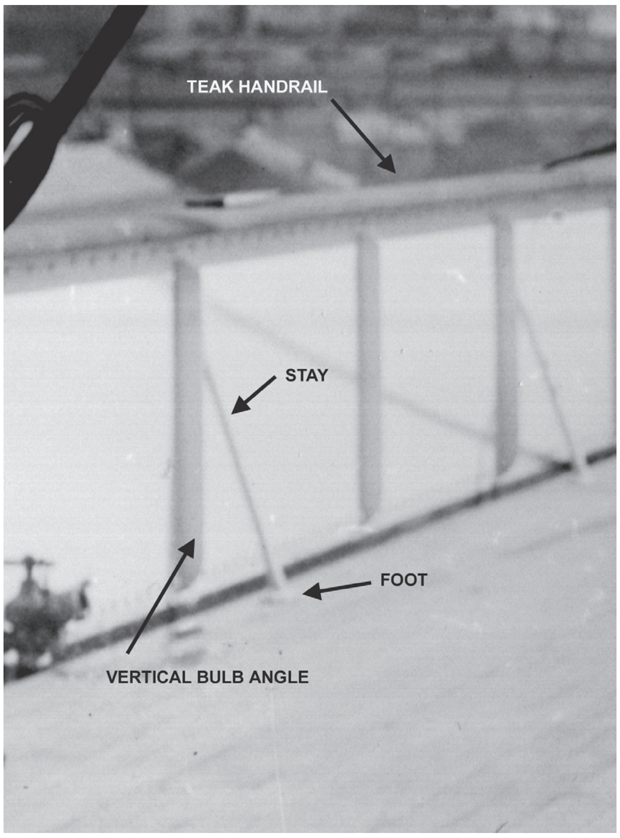


Fig. 12-1 **Boat Deck Bulwark on *Olympic*** – A section of the starboard Boat Deck bulwark on *Olympic*.

The bulwarks enclosing each Well Deck at the ship's sides were stiffened by bulb angles and stays in the same manner as bulwarks mentioned above, the exception being that a stay was provided behind each stiffener as well as on both sides of each gangway door.

Due to their additional height, the curved forward bulwarks abeam of the Navigating Bridge (between the Bridge and the wing cabs) were fitted with supplemental supports. In this instance, each bulwark stay was provided

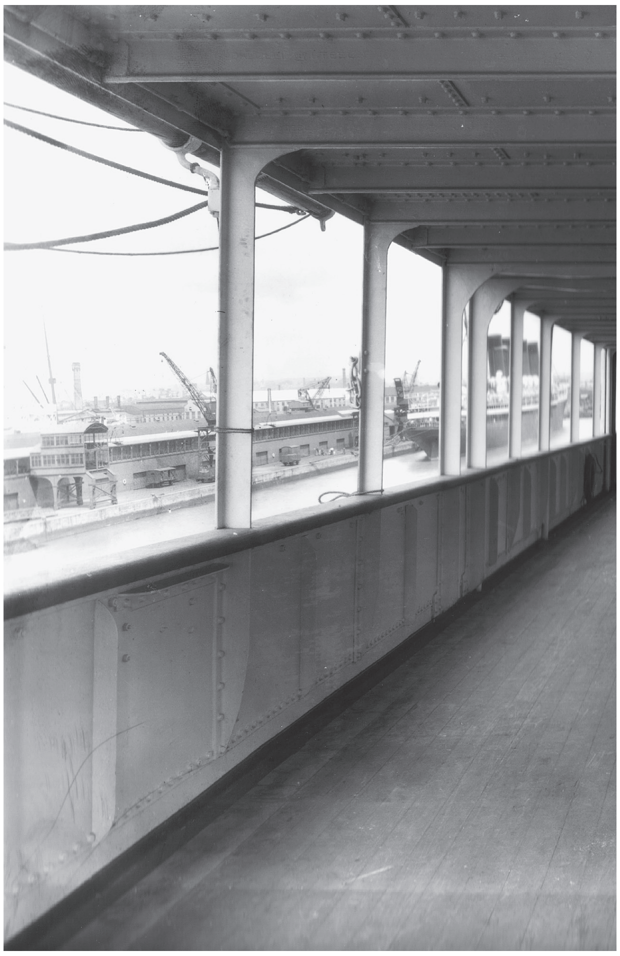


Fig. 12-2 **A Deck Bulwark** – A photograph of *Olympic*'s A Deck bulwark, showing the frame legs that supported the outboard ends of the transverse beams of the Boat Deck above.

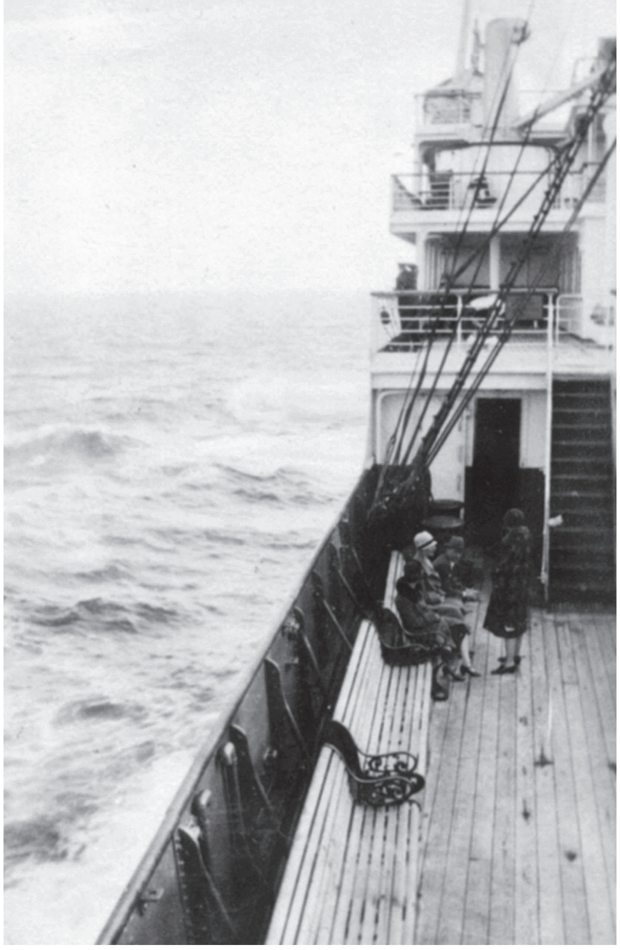


Fig. 12-3 **After Well Deck Bulwark** – *Olympic*'s after Well Deck bulwark on the port side. This photograph dates from later in her career, as is evident from the benches that have been added to this location. *(Peter Davies-Garner collection)*

with an additional horizontal bar, called a 'spur' or 'fork', located about halfway up the stay. The spurs helped to distribute the support provided by each stay as evenly as possible along the height of the bulwark stiffeners. As with the tops of the stays, the end of each spur was flattened into a palm for attachment to the adjacent stiffener.

Board of Trade regulations required that stays and stanchions be fastened to the deck with tap bolts, also known as tap rivets. Tap bolts were used instead of clinched rivets in order to ensure the watertight integrity of the deck through which they were fitted. If conventional clinched rivets were used to secure the

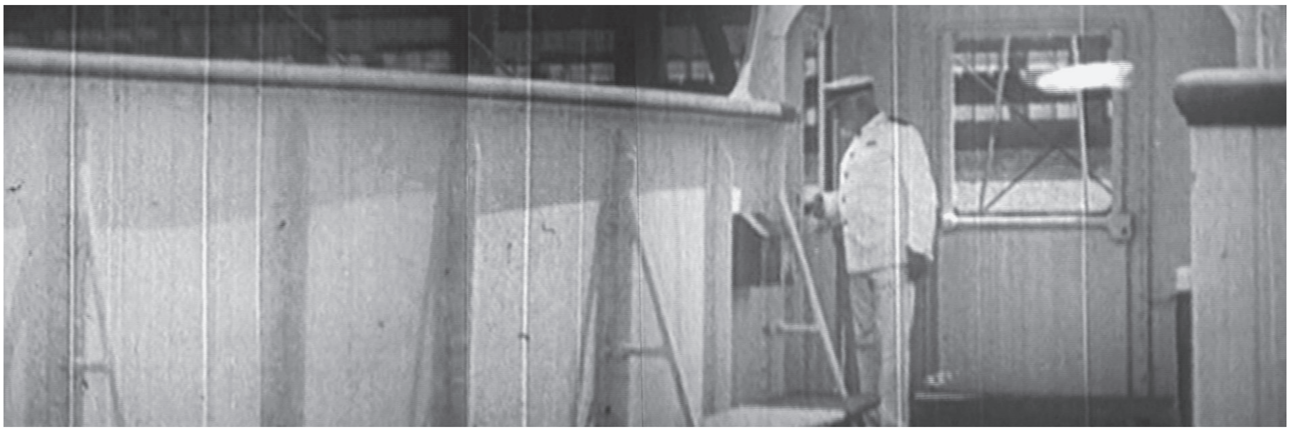


Fig. 12-4 **Bridge Bulwark Mosaic** – Captain Smith on the starboard Bridge wing of *Olympic*, filmed at New York on her maiden voyage. This image is a mosaic of multiple frames from a promotional film. The horizontal 'spurs' on the stays can be seen here. The low platform following the contour of the bulwark is a teakwood step. *(From an original White Star Line promotional film/Authors' collection)*

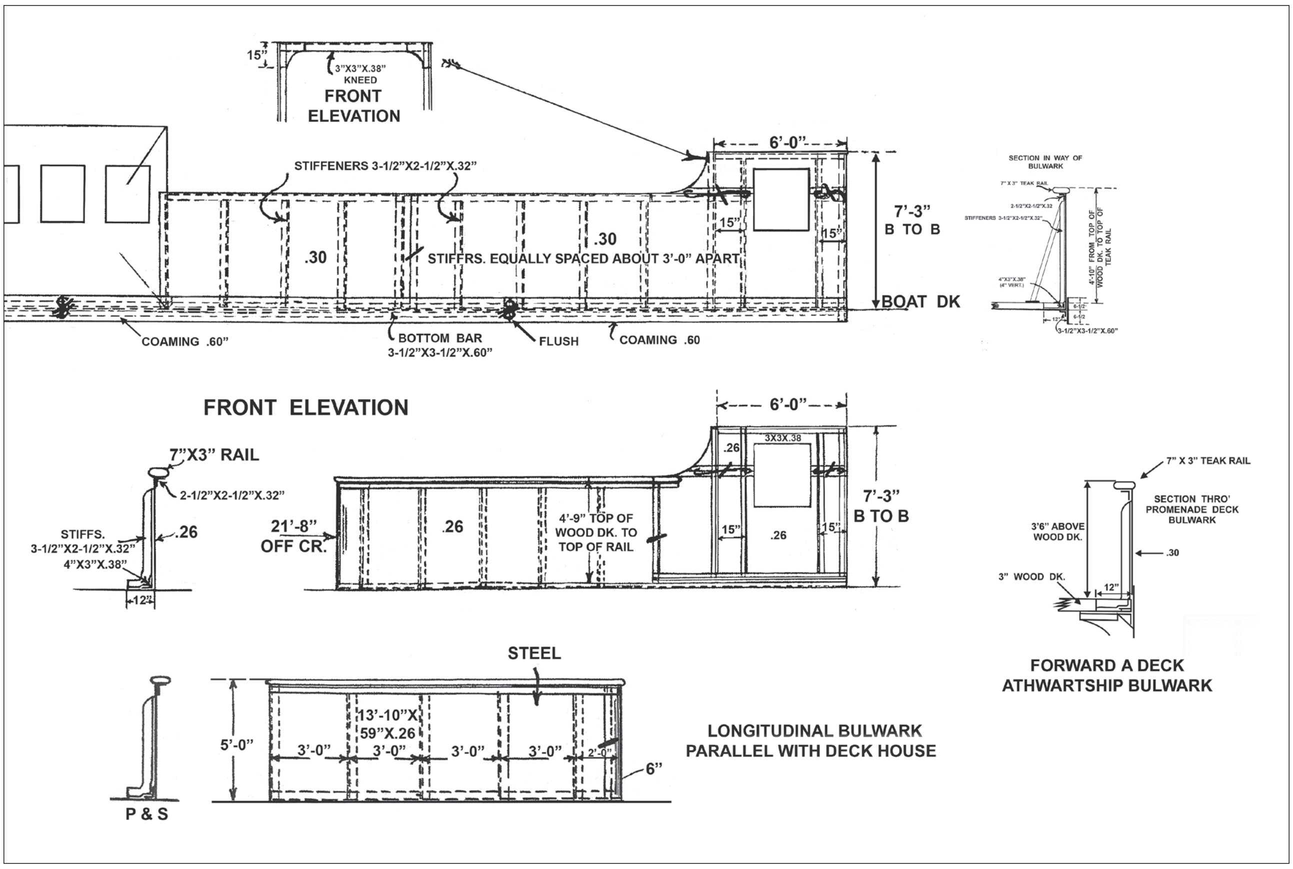

15"
3"X3"X.38" KNEED
FRONT ELEVATION
STIFFENERS 3-1/2"X2-1/2"X.32"
6'-0"
15"
15"
7'-3" B TO B
.30
.30
STIFFRS. EQUALLY SPACED ABOUT 3'-0" APART
BOAT DK
COAMING .60"
BOTTOM BAR 3-1/2"X3-1/2"X.60"
FLUSH
COAMING .60
SECTION IN WAY OF BULWARK
7" X 3" TEAK RAIL
2-1/2"X2-1/2"X.32
STIFFENERS 3-1/2"X2-1/2"X.32"
4"X3"X.38" (4" VERT.)
4'-10" FROM TOP OF WOOD DK. TO TOP OF TEAK RAIL
6-1/2
6-1/2
12"
3-1/2"X3-1/2"X.60"
FRONT ELEVATION
7"X3" RAIL
2-1/2"X2-1/2"X.32"
STIFFS. 3-1/2"X2-1/2"X.32"
4"X3"X.38"
.26
12"
21'-8" OFF CR.
.26
4'-9" TOP OF WOOD DK. TO TOP OF RAIL
6'-0"
3X3X.38
.26
15"
.26
15"
7'-3" B TO B
7" X 3" TEAK RAIL
SECTION THRO' PROMENADE DECK BULWARK
3'6" ABOVE WOOD DK.
.30
3" WOOD DK.
12"
FORWARD A DECK ATHWARTSHIP BULWARK
STEEL
5'-0"
13'-10"X 59"X.26
3'-0"
3'-0"
3'-0"
3'-0"
2'-0"
6"
LONGITUDINAL BULWARK PARALLEL WITH DECK HOUSE
P & S

Fig. 12-5 **Forward Boat Deck Bulwarks** – A drawing based on the original Boat Deck Iron drawings showing the bulwarks in the area of the Bridge. Note that while the drawing figures detail the steel bulwarks bounding the after end of the Bridge for 401 *(Titanic),* the inboard longitudinal bulwarks abeam of the Wheelhouse are still the same length as the wooden bulwarks of the pre-1913 *Olympic.* This drawing shows the initial design of these bulwarks prior to the decision to extend the Officers' Quarters deckhouse forward by 9ft, which resulted in these bulwarks being shortened by the same amount. Also, these figures show the original design of the Bridge wing cabs which, on *Olympic* were built flush with the sides of the deck. During her fitting-out, *Titanic*'s wing cabs were extended overboard by 18in to give a better view aft from the Bridge. *(Illustration by Bruce Beveridge based on original H&W plan)*

stays to the decking and they sustained damage to the point that the heads sheared off, the shank would also be loosened or pulled free leaving an opening where water could enter and find its way to the space below. With a tap bolt, a threaded end was screwed through the steel deck, tightly filling the hole, while the head firmly held in place the object to be attached. This type of fastener was designed so that if the head were to break off, the threads would provide a natural stress point allowing the head to snap clean from the shank with the bottom portion remaining in the hole, thereby preventing water from entering. To ensure a watertight seal, the tap bolts were fitted in conjunction with grommets and white-lead paint. This form of securing the stays to the steel decking was even more critical when the bulwark was fitted away from the edge of the deck and located above a passenger compartment, as was the case with the port and starboard after bulwarks abeam of the bridge.

Folding gangway doors

On *Titanic*, as with many other large passenger liners, large gangway doors were provided in the bulwarks opposite each hatchway to avoid having to lift cargo over the bulwarks. A pair of these doors was located on both sides of *Titanic*'s Well Decks. The Well Deck bulwarks and their gangway doors were designed as a faired continuation of the surface of the hull below, providing a continuity of appearance along the sheer line of the hull. These doors were secured to the curtain plate by rivets incorporating special hinges. When closed, they were locked in position by sliding bolts and buttressed by portable stays. To make up for the transverse weakness of the bulwarks due to the discontinuity introduced by these large gangway doors, the Well Deck bulwarks were particularly well stayed. This was necessary because in addition to the punishment caused by heavy seas, these bulwarks were occasionally subjected to heavy blows from swinging cargo.

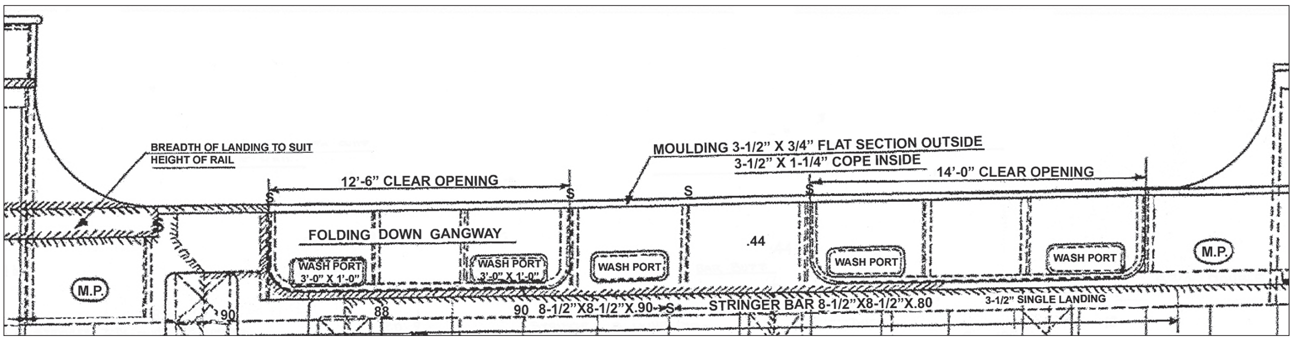

BREADTH OF LANDING TO SUIT
HEIGHT OF RAIL
12'-6" CLEAR OPENING
MOULDING 3-1/2" X 3/4" FLAT SECTION OUTSIDE
3-1/2" X 1-1/4" COPE INSIDE
14'-0" CLEAR OPENING
S
S
S
S
FOLDING DOWN GANGWAY
.44
WASH PORT 3'-0" X 1'-0"
WASH PORT 3'-0" X 1'-0"
WASH PORT
WASH PORT
WASH PORT
M.P.
M.P.
90
88
90 8-1/2"X8-1/2"X.90
S
STRINGER BAR 8-1/2"X8-1/2"X.80
3-1/2" SINGLE LANDING

Fig. 12-6 **Forward Well Deck Folding Gangway Doors** – *(Illustration by Bruce Beveridge based on original H&W Shell Plating plan)*

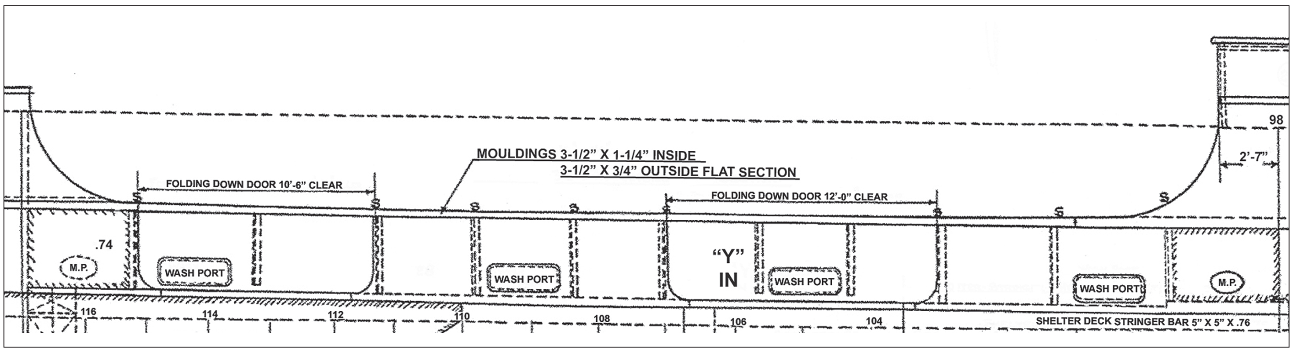
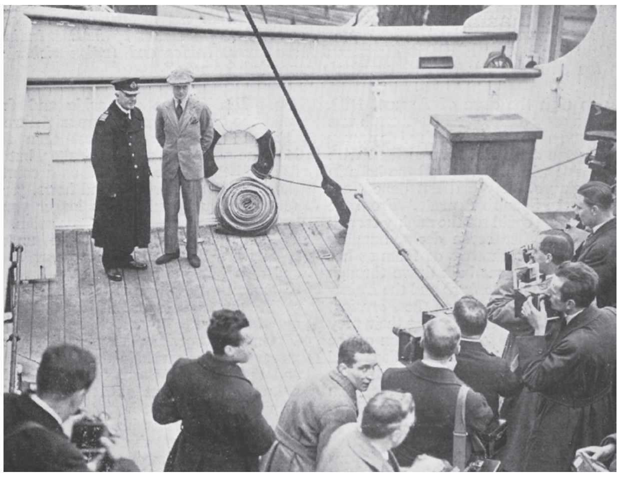
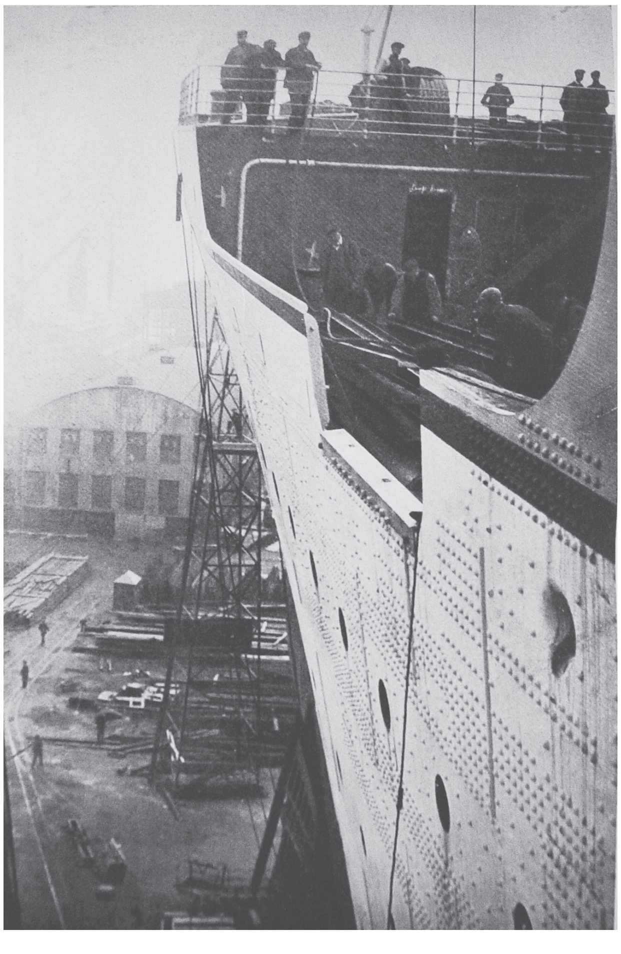

98
MOULDINGS 3-1/2" X 1-1/4" INSIDE
3-1/2" X 3/4" OUTSIDE FLAT SECTION
2'-7"
FOLDING DOWN DOOR 10'-6" CLEAR
FOLDING DOWN DOOR 12'-0" CLEAR
S
S
S
S
S
S
S
S
.74
M.P.
WASH PORT
WASH PORT
"Y"
IN
WASH PORT
WASH PORT
M.P.
116
114
112
110
108
106
104
SHELTER DECK STRINGER BAR 5" X 5" X .76

Fig. 12-7 **After Well Deck Folding Gangway Doors** – *(Illustration by Bruce Beveridge based on original H&W Shell Plating plan)*



Above Fig. 12-8 **H.R.H. the Prince of Wales with *Olympic*'s Captain Howarth** – Captain Howarth of *Olympic* posing with Edward, Prince of Wales, in October 1924. Behind them is the starboard after bulwark abeam of the Wheelhouse. On *Olympic* this bulwark was wooden, but on *Titanic* it was steel. *(Craig Mestach collection)*



Right Fig. 12-9 **Forward Well Deck Bulwark on *Olympic*** – This pre-launch photo of *Olympic* provides a unique outboard view showing one of her forward Well Deck gangway doors removed. *(Art Braunschweiger collection)*

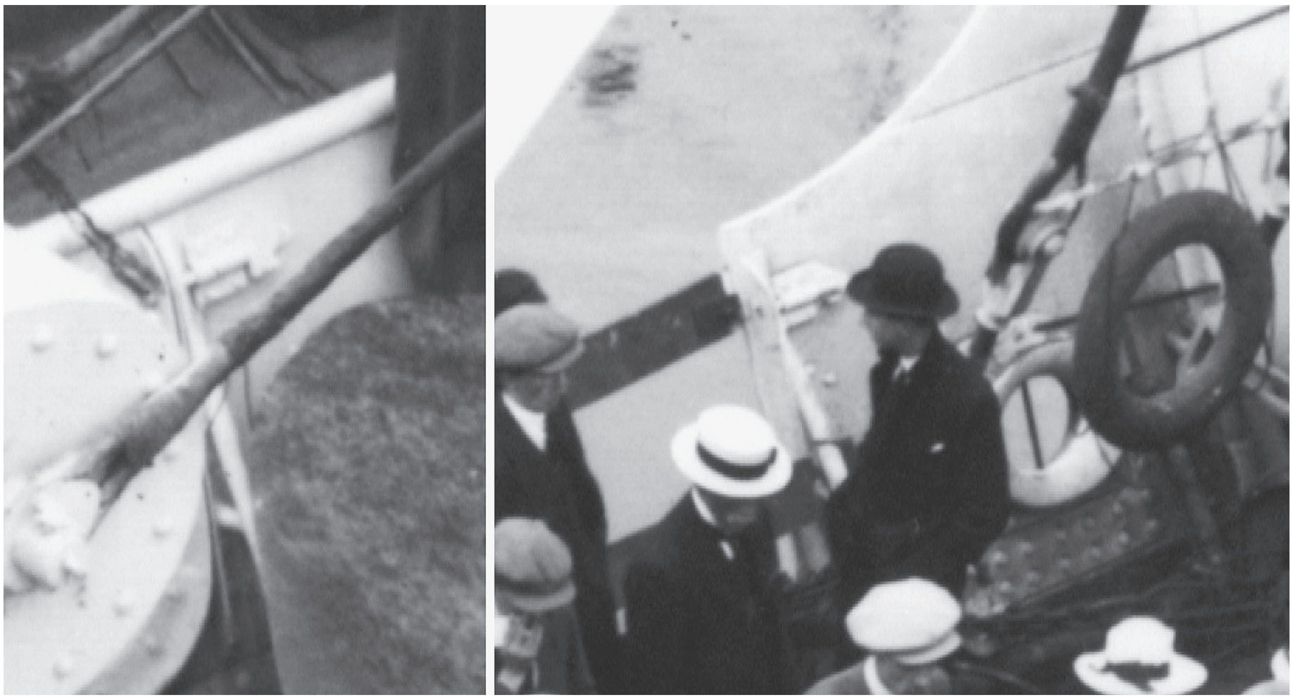


Fig. 12-10 **Bolts for Removable Gangway Doors** – Enlarged photo details showing the inboard sides of *Olympic*'s removable gangway doors in her forward Well Deck. The securing bolts are plainly visible. *(Both images authors' collection)*

In addition to folding doors located opposite the cargo hatches, the bulwarks along the sides of A and B Decks were fitted with a number of both hinged and removable doors to accommodate the loading of provisions, furniture and other shipboard fittings and supplies, as well as providing alternate entrances from which to rig gangways for the boarding of passengers. Like the Well Deck gangway doors, these doors also were formed to provide an uninterrupted visual continuation with the surface of the surrounding bulwark plates.

Wash ports

To clear the deck of larger volumes of water than could be readily handled by the scuppers, hinged ports called 'wash ports'[1] were fitted in the Well Deck bulwarks and gangway doors. These ports were fitted with lids hinged at the upper side and arranged so that the covers only opened outward. This allowed any seas shipped to be quickly cleared from the deck while preventing the readmission of water back through the wash ports from outside the bulwarks. Means were provided for fastening the lids in the open position (also called 'tricing them up') when it was not necessary that they be kept closed. The openings were 3ft wide by 1ft high and protected with horizontally fitted guard rods (two each forward, and one each aft) to prevent both people and equipment from being washed overboard through them.

Railings and stanchions

Railings were fitted to open decks such as the Forecastle and Poop Decks, along the outer edges of deckhouse roofs and sometimes to the uppermost open deck of the superstructure. On *Titanic*, they were employed at the after end of all the open decks on the superstructure. As with the bulwarks, they were fitted for the same reasons of safety.

Unlike bulwarks, which are solid in construction, railings are open structures composed of rails and stanchions. They are designed to permit the free passage of both wind and water while at the same time acting as a safety barrier to prevent objects and people from falling or being washed overboard. The term 'stanchion' refers to the vertical bars that support the rails; the term 'rail' denotes the horizontal bars or pipes that form the actual barrier. The weather decks were fitted with many different railing configurations, varying from only one horizontal railing to as many as five. The top railing was either plain steel, or, along passenger decks on the superstructure, fitted with teakwood top rails.

Where decks with passenger access were bounded only by open rails, the space between the rails was to be not more than 6in center-to-center. In no case was the height of the top rail to be less than 3ft 6in above the deck. The railing stanchions on *Titanic* were spaced on 4ft centers. Commonly they were 1½in in diameter at the top and 1¾in in diameter at the bottom; generally, stanchions were always wider at the bottom then at the top. They were

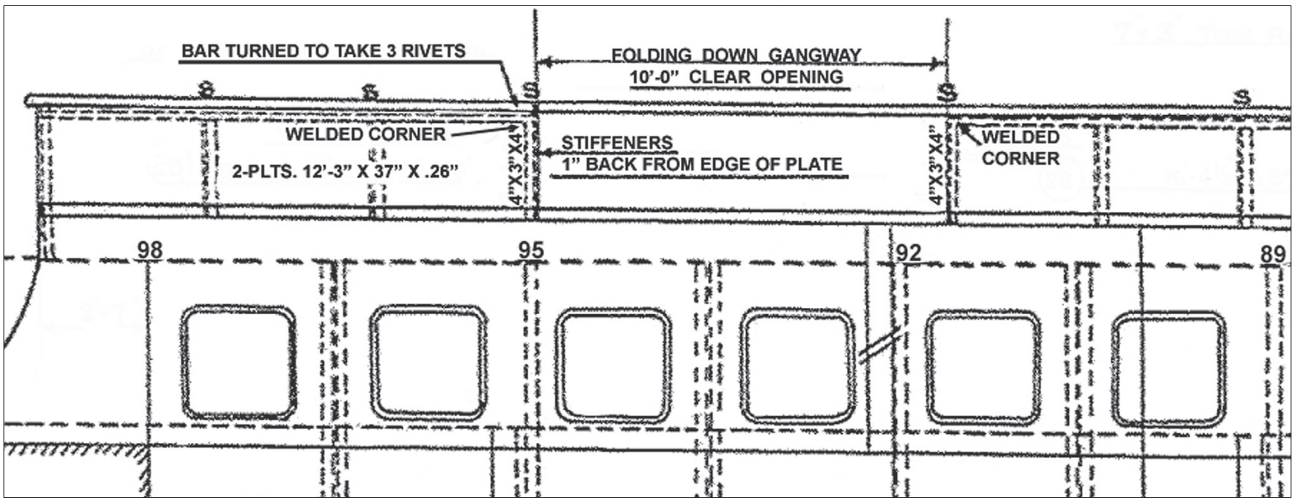

BAR TURNED TO TAKE 3 RIVETS
FOLDING DOWN GANGWAY
10'-0" CLEAR OPENING
WELDED CORNER
2-PLTS. 12'-3" X 37" X .26"
4"X3"X4"
STIFFENERS
1" BACK FROM EDGE OF PLATE
4"X3"X4"
WELDED CORNER
98
95
92
89

Fig. 12-11 **B Deck Folding Gangway Door**. *(Illustration by Bruce Beveridge based on original H&W plan)*

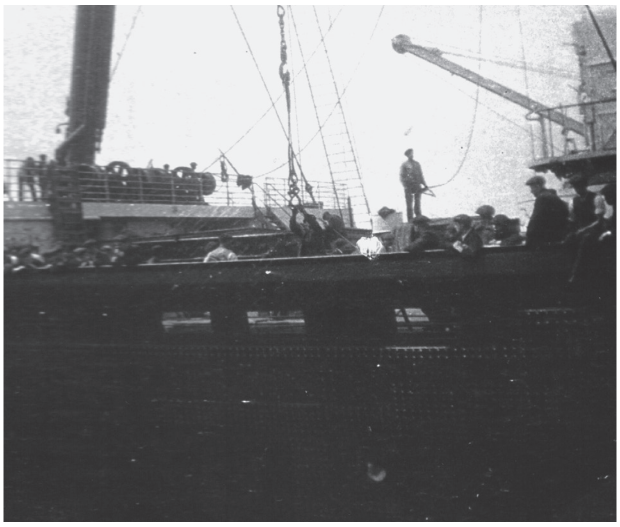


Fig. 12-12 **Wash Ports Open on *Olympic*** – A view of *Olympic* from the wharf. Three of her wash ports are triced open and the double guard rods are visible.

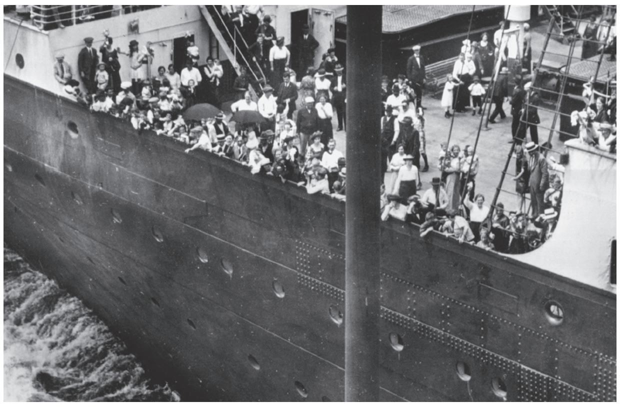


Fig. 12-13 **Well Deck Gangway Doors and Wash Ports** – Passengers crowd along the starboard bulwark of *Olympic*'s after Well Deck. The wash ports are shown here in their closed position.

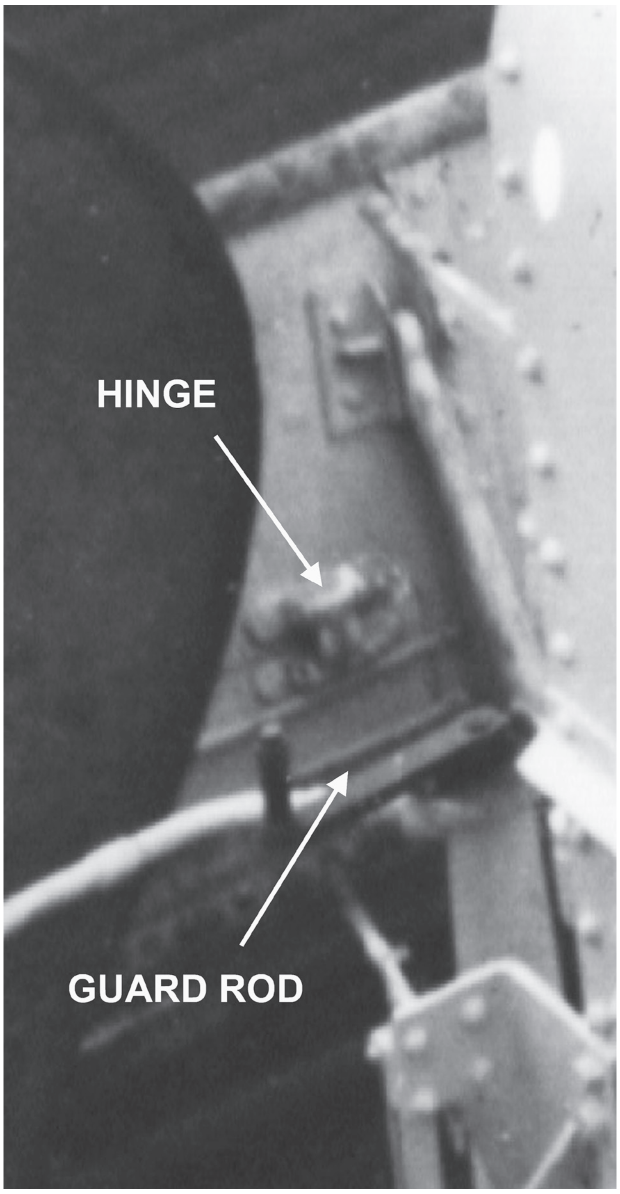

HINGE
GUARD ROD

Fig. 12-14 **Wash Port Mechanism** – This enlarged photograph detail shows a wash port door hinge and two horizontal guard rods on the inboard side of one of *Olympic*'s forward Well Deck bulwarks.

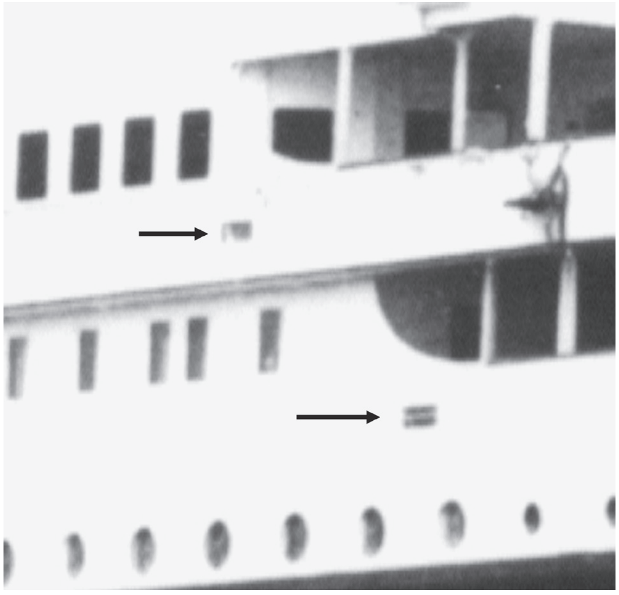


Fig. 12-15 **A and B Deck Wash Ports** – The wash ports at the forward end of A and B Decks on *Titanic*. Each wash port at these locations had one guard rod.

made thicker in diameter when fitted in areas susceptible to higher stresses from the elements. Stanchions were made of galvanized iron, forged under a steam hammer from stout bar stock. The intersection with the rails was achieved through what appeared as a 'ball' at each elevation. A hole was drilled through each of these balls after forging, which created a loose fit for the rails.

After the rails were passed through, wedging and caulking was used to tighten them in place. On the Forecastle and Poop Decks, excepting those areas bordering the Well Decks, the stanchions were riveted directly to the inboard side of the sheer strakes. On the forward side of the Poop Deck and the aft side of the Forecastle Deck, the railings were riveted to the 6in steel wash plates.

As with the bulwarks, the railings were also supported by stays in certain areas such as adjacent to a fairlead where a section of railing would have been portable (removable) to allow access for mooring lines. This was the case on the Forecastle and Poop Decks. On the Boat Deck, the railings used to create the barriers between the various promenade areas were designed to be portable; when in place they were fastened by screws into deck sockets (or brass cups as they are sometimes called), set flush into the planking.

Wooden top rails, where fitted, were made of teak.[2] These were intended for passengers to lean on when looking out to sea. The nomenclature given to these wooden rails varied not only by shipyard, but according to the location on the ship as well; 'guardrails' and 'accommodation rails' were commonly used terms.

The wooden rails were fastened to the heads of the stanchions with flat-head bolts, sunk into the top of the rail to a depth of half an inch. The undersides of the bolt heads were coated with lead paint and oakum. To cover the head of the bolt and plug the hole in the rail, a dowel coated with paint around its circumference was driven in tight and trimmed flush.

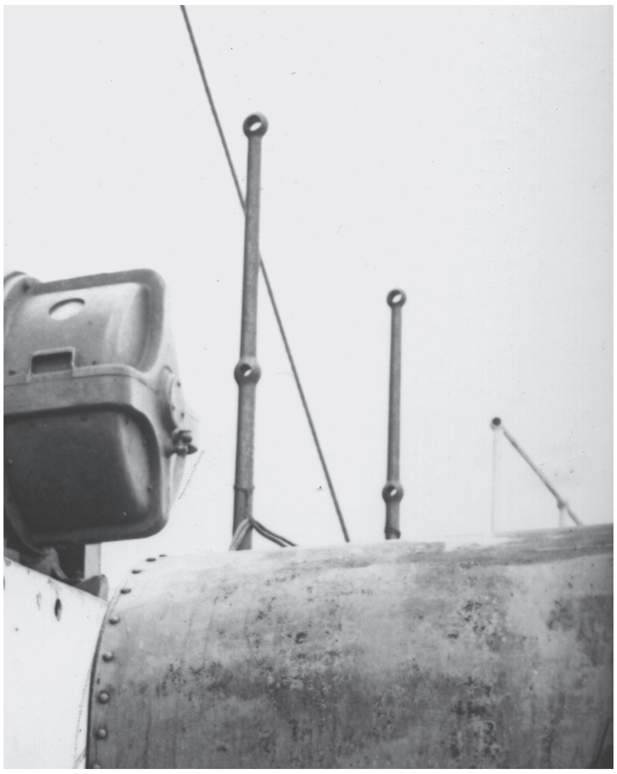


Fig. 12-16 **Railing Stanchions** – Stanchions on *Olympic* during construction, shown prior to the rails being inserted. *(H&W/Authors' collection)*

Joining two lengths of rail was accomplished by a simple process. The joint was halved and mitered, the halving terminated in a manner not visible on the edges of the rail. The rounded portion was mitered, the flat part was halved and the joint held together by screws. When fitting a round corner, a separate piece was made to the required radius and was jointed at each end to the adjacent straight lengths. The joints were halved and screwed; the molded portion was butted. Such joints were not made at the exact point of transition from the rounded to the straight portion of the rail, but were instead carried a minimum distance of 2in beyond this point because it was much easier to make the joint with the abutting pieces in a straight line.

Awning rafters and stanchions

In the summer, during times of hot weather, canvas awnings could be erected to provide shade above certain deck areas and above the roof of the Officers' Quarters deckhouse. These awnings were supported by wooden rafters and/or wire strung tightly between

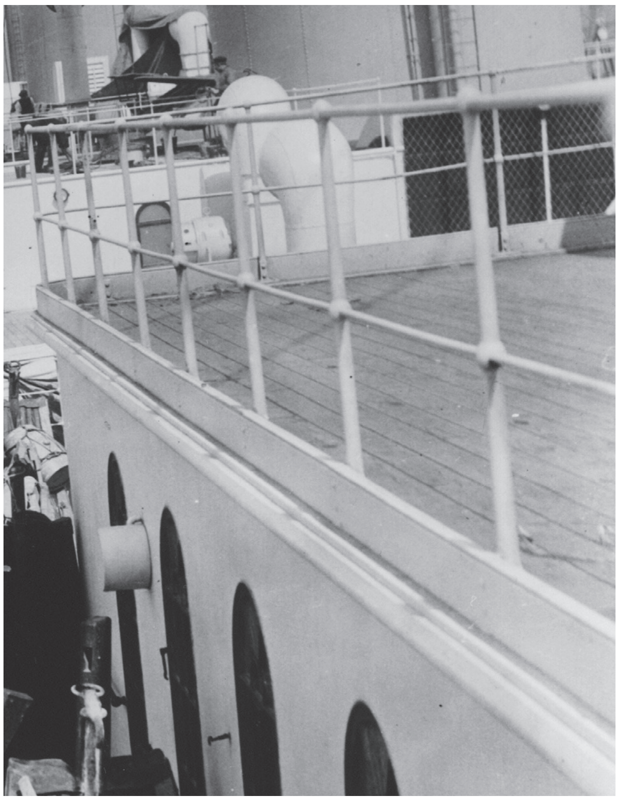


Fig. 12-17 **Railing Over Officers' Quarters Deckhouse** – A railing over the *Olympic*'s Officers' Quarters deckhouse. The 'balls' at each stanchion through which the rails passed are plainly visible.

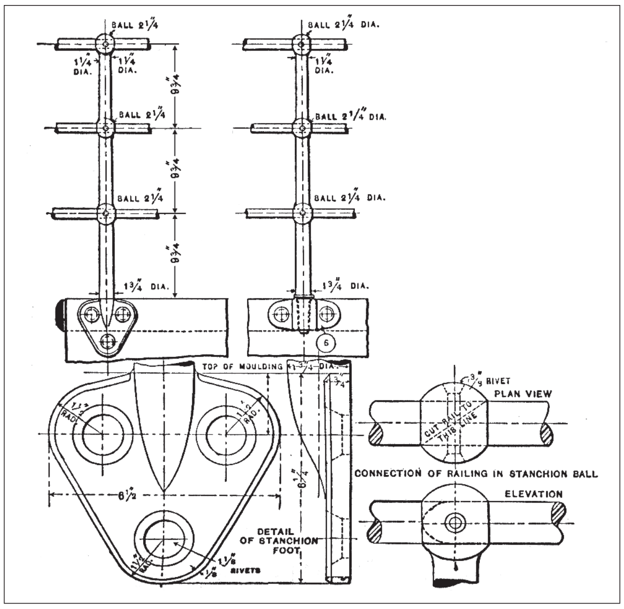

BALL 2¼
BALL 2¼ DIA.
1¼ DIA.
1¼ DIA.
9¾
BALL 2¼
BALL 2¼ DIA.
BALL 2¼
BALL 2¼ DIA.
1¾ DIA.
1¾ DIA.
6
TOP OF MOULDING
¾ RIVET
PLAN VIEW
CUT BALL TO THIS LINE
CONNECTION OF RAILING IN STANCHION BALL
ELEVATION
6½
DETAIL OF STANCHION FOOT
1⅛ RIVETS

Fig. 12-18 **Railing Stanchions** – Drawing showing the details typical to shipboard open railings. Rivets were another way to secure the rail bars through the stanchion balls instead of wedging. The dimensions of the fittings shown are generic, and not specific to *Titanic*.

stanchions. Rafters were of wood. Stanchions were of light tubing with solid welded ends, the upper parts being suitably formed to support the ends of wooden cross rafters and to take the fore-and-aft ridge lines or wire. The awning stanchions, fitted around the ship in specified places, were generally portable and were usually connected to the washboards beside the stanchions for the railings. Other specially designed stanchions were designed to be mounted within deck sockets for areas not contiguous with a rail or other supporting structure.

Fittings for awnings were known to be present on *Titanic* above the Officers' Quarters deckhouse, over the after Well Deck above the Nos 5 and 6 Hatches, and at the after end of A Deck. The Officers' Quarters deckhouse roof was provided with a permanent awning rafter. The after end of this rafter was mounted on the head of the Gibbs extractor ventilator located on the centerline over the Elevator Machinery Room; from here the rafter extended forward to the hood of the stokehold vent for the No. 5 Boiler Room.

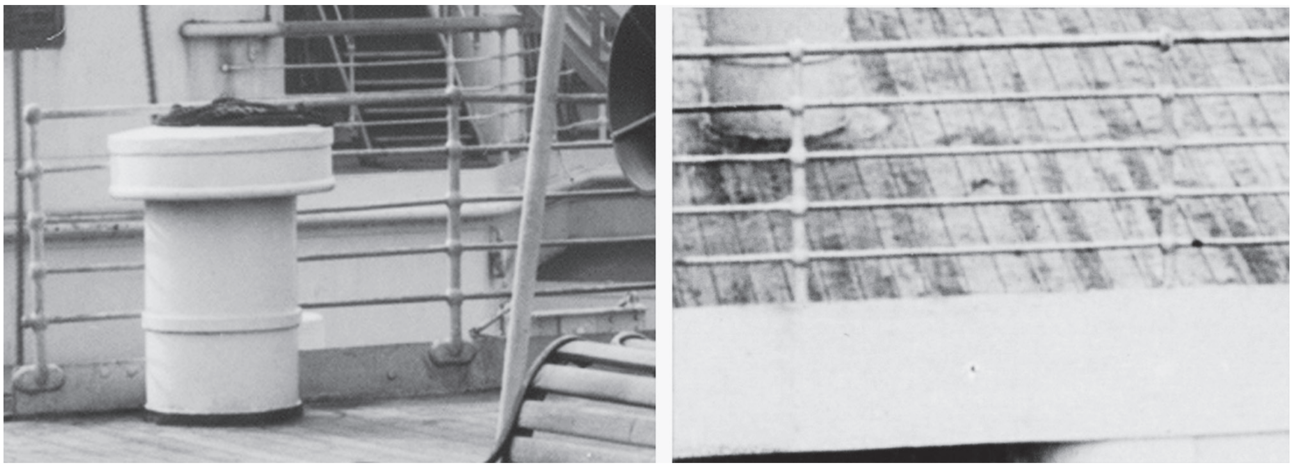


Fig. 12-19 **Poop Deck Railings** – At right, a section of railing at the forward end of *Titanic*'s Poop Deck. At left, a late *Olympic* image of the forward end of the Poop Deck (the ventilator head was added later in her career). The stanchions are riveted to a 6in wash plate, sometimes referred to as a coaming. *(Both images authors' collection)*

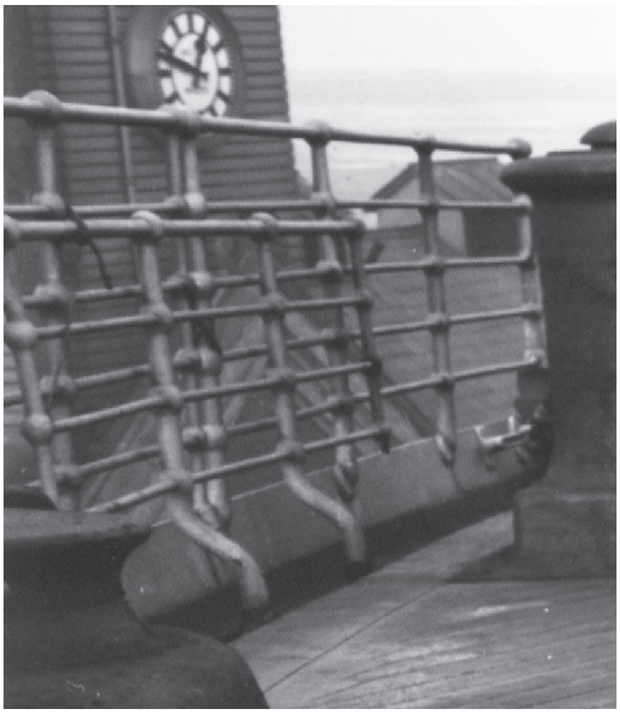


Fig. 12-20 **Forecastle Deck Railing** – A section of railing on *Olympic*'s Forecastle Deck showing the inside riveting at the sheer strake, and one of the portable railing sections resting against its permanently fitted counterpart.

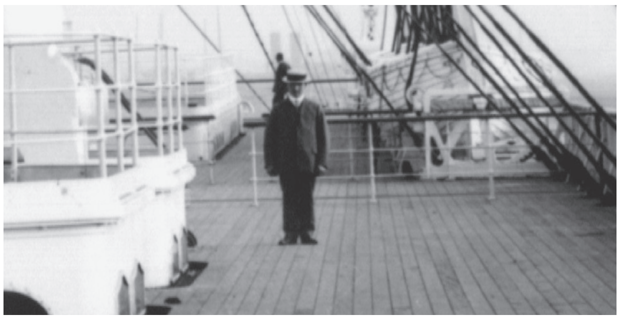


Fig. 12-21 **Boat Deck Promenade Barrier Railing** – In this view looking aft, a man stands on the port side of *Olympic*'s Boat Deck. In the background, with the gates removed, are the barrier railings which divided the short Engineers' Promenade from the First Class Promenade in the foreground, and from the Second Class Promenade aft. *(H&W/Authors' collection)*

Around the fidley deck above the Nos 5 and 6 Boiler casing, permanent stanchions were riveted to the plating forming the perimeter and had a wire passed through them. The awning at this location would have shaded the roof over the Officers' Quarters deckhouse on the port and starboard side of the No. 1 Funnel.

In the after Well Deck, rafter brackets were installed on the forward edge of the Poop Deck and the after edge of B Deck, both mounted along the centerline of the ship. A rafter was also fitted over the aft end of A

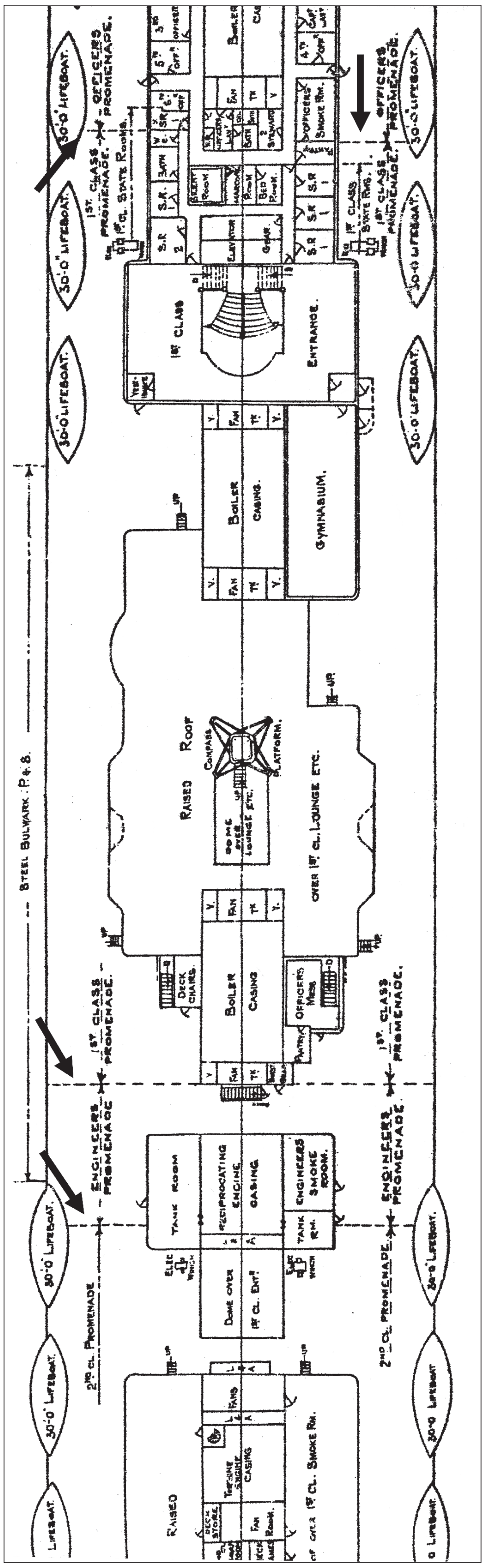

30'-0" LIFEBOAT.
OFFICERS PROMENADE.
1ST CLASS PROMENADE.
1ST CL. STATE ROOMS.
1ST CLASS ENTRANCE.
BOILER CASING.
GYMNASIUM.
RAISED ROOF
COMPASS PLATFORM.
DOME OVER 1ST CL. LOUNGE ETC.
OVER 1ST CL. LOUNGE ETC.
STEEL BULWARK. P. & S.
DECK CHAIRS.
OFFICERS MESS.
ENGINEERS PROMENADE.
TANK ROOM
RECIPROCATING ENGINE CASING
ENGINEERS SMOKE ROOM.
DOME OVER 1ST CL. ENTCE
2ND CL. PROMENADE
TURBINE ENGINE CASING
2ND CL. SMOKE RM.
RAISED

Fig. 12-22 **Plan Showing Boat Deck Promenade Barriers** – This detail is from a Harland & Wolff plan dated 1914, submitted for the Limitation of Liability hearings in the United States. It shows the exact location of *Titanic*'s promenade barrier railings, which have been picked out on the image with arrows drawn by the author. The exact location of these railings on *Titanic* has been a source of confusion for years, due to the fact that *Olympic*'s railings, both in 1911 and after the 1912-13 refit, were in slightly different locations than *Titanic*'s. *(National Archives/Authors' collection)*

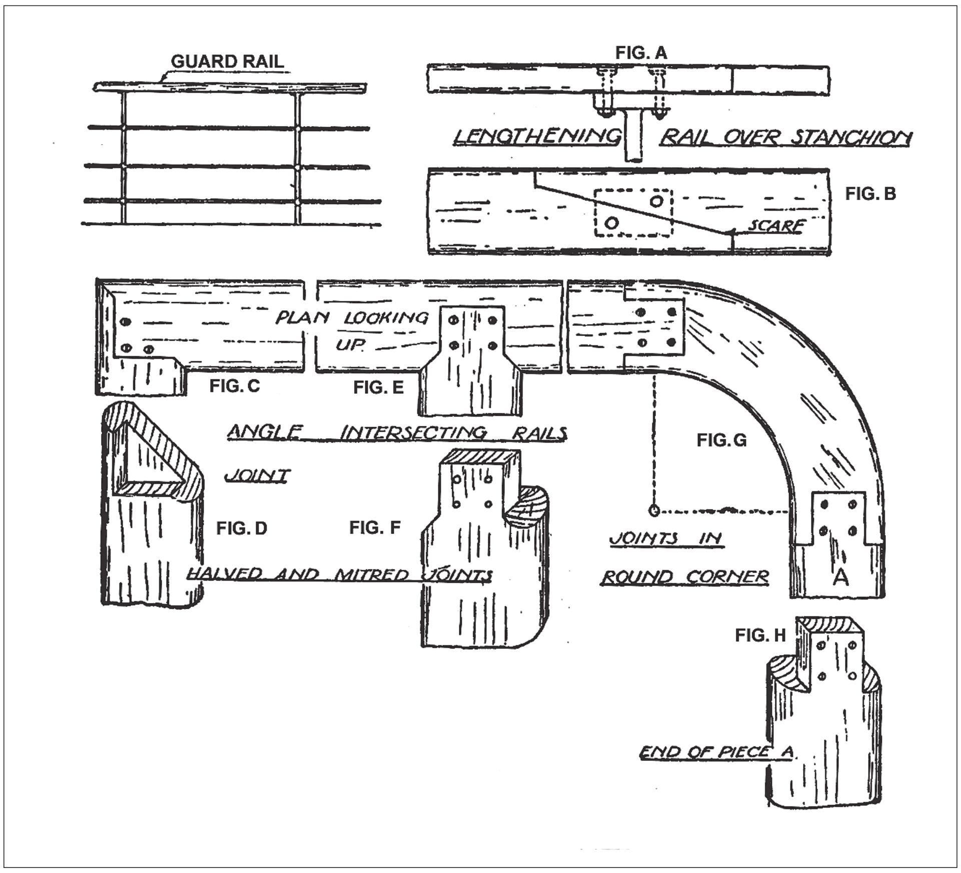


Fig. 12-23 **Wood Top Rail Joints** – Figs. A and B show the top side views of a typical scarf used to join the straight lengths of a wood top rail over a stanchion. Figs. C through H show the methods employed in joining together the various intersections and corners of wood top rails as viewed from the underside of the rail: Figs. C & D – right angle corner; Figs. E and F – right-angle intersection; Figs. G and H – joinery of a round corner.

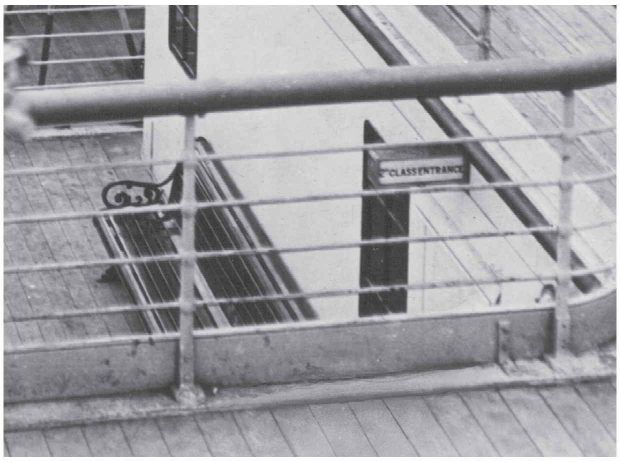


Fig. 12-24 **Railing with Teak Top Rail** – A railing with a teakwood top rail at the after end of A Deck on *Titanic. (*Cork Examiner*/Authors' collection)*

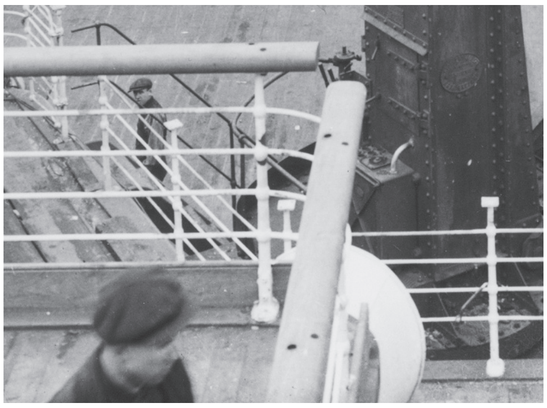


Fig. 12-25 **Railing Under Construction –** A section of *Olympic*'s railing at the aft end of B Deck while under construction. The rounded corner piece is still absent in this photo, as are the plugs which will cover the heads of the bolts attaching the top rail to the stanchions beneath. *(H&W/Authors' collection)*

Deck, between the mainmast and the Boat Deck margin plate. This rafter was portable and could been seen on *Olympic* later in her career supporting a passenger swing for the passengers' recreation.

Canvas weather screens were also provided on *Titanic*. An example of these screens can be seen in the photographs of *Titanic* at Queenstown, when a half-length canvas awning was deployed along both sides of A Deck in the area of the open section of the promenade space. Jackstays were also fitted for weather shielding by use of canvas along the forward faces of the bulwarks of the superstructure, the Crow's-nest, and just below the rail at the Forecastle head for those times when extra lookouts were positioned at the 'eyes' of the ship. Later photographs of *Olympic* taken in cold weather also show canvas screens lashed to the railings of the Boat Deck, Poop Deck, Docking Bridge and the railings at the aft end of A and B Decks.

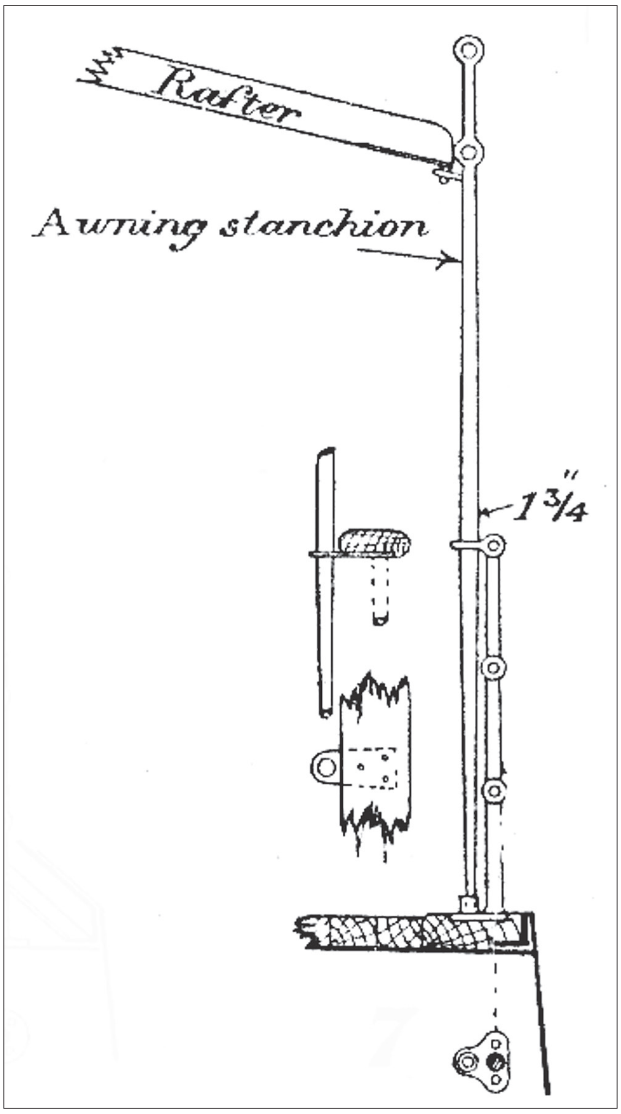


Fig. 12-26 **Awning Stanchion** – Drawing of a typical awning stanchion with rafter attachment. *(*Practical Shipbuilding*/ Authors' collection)*

General Specifications of bulwarks and railings

Boat Deck Bulwarks (measurements from top of deck to top of teak rail)

Extreme forward bulwarks port and starboard of Navigating Bridge: 4ft 10in high, teak rail 7in x 3in; stiffened at approximately 3ft intervals, stayed at every other stiffener.

Forward port and starboard longitudinal steel bulwarks along ship's side abaft Bridge wing cabs to approximately midway between frames 60F and 61F: 4ft 0in high, teak rail 8in x 3in; stiffened and stayed with two stays per plate.

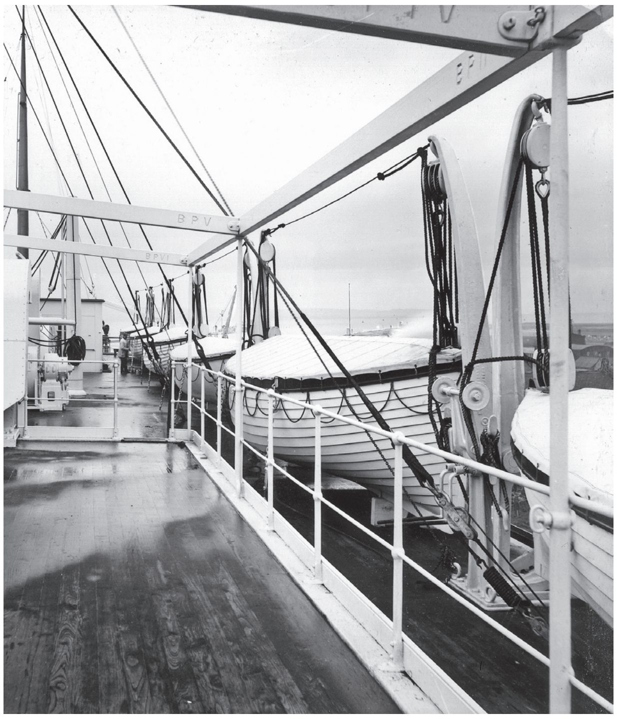


Fig. 12-27 **Awning Rafters on *Asturias* –** Canvas awnings were commonplace on ships of the steam era. This image shows the Royal Mail Steam Packet Company's *Asturias*, launched by Harland & Wolff in 1907. *(H&W/Authors' collection)*

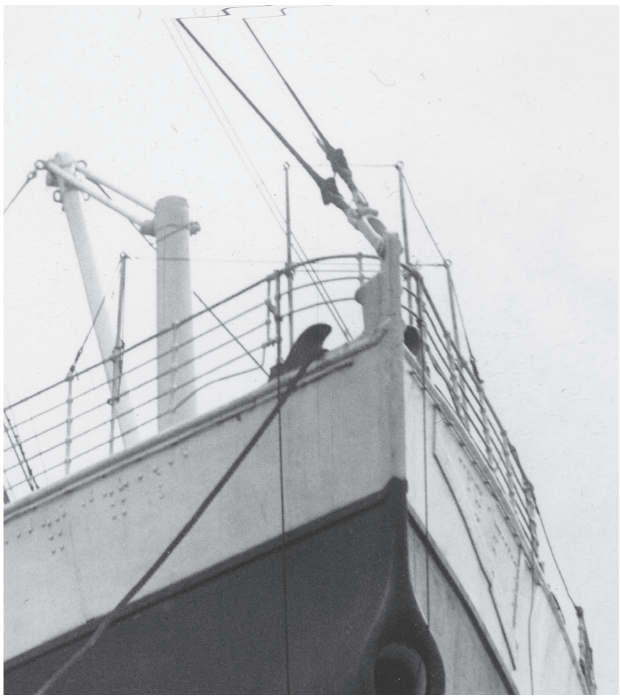


Fig. 12-28 **Canvas Screen Stanchions** – The *Olympic*-class liners were also fitted with canvas screens. Seen here are the stanchions fitted to the railings at *Olympic*'s Forecastle head for the temporary fitting of a canvas screen.

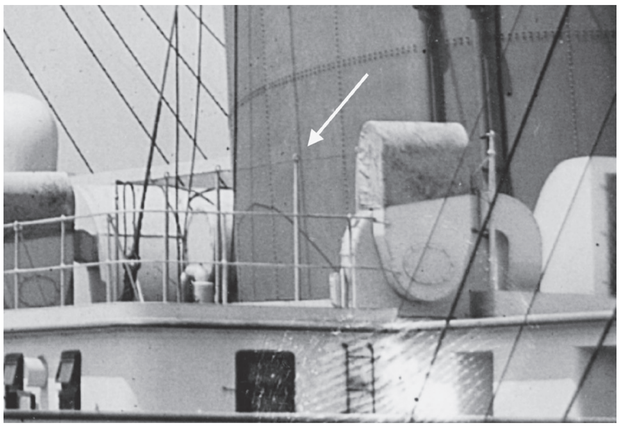


Fig. 12-29 **Awning Stanchions Beneath No.1 Funnel** – Flanking the boiler casing at the base of the No.1 Funnel on *Olympic* and *Titanic* were stanchions supporting a wire jackstay used to secure an awning, as seen in this image of *Olympic*.

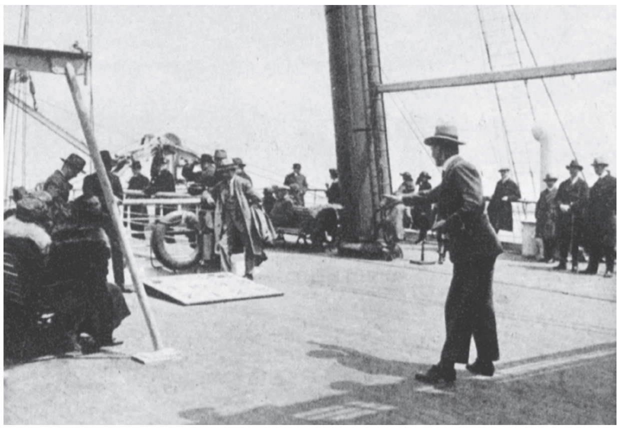
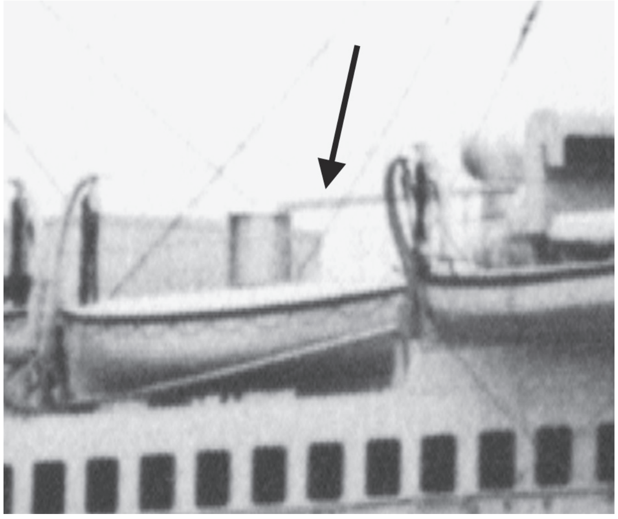
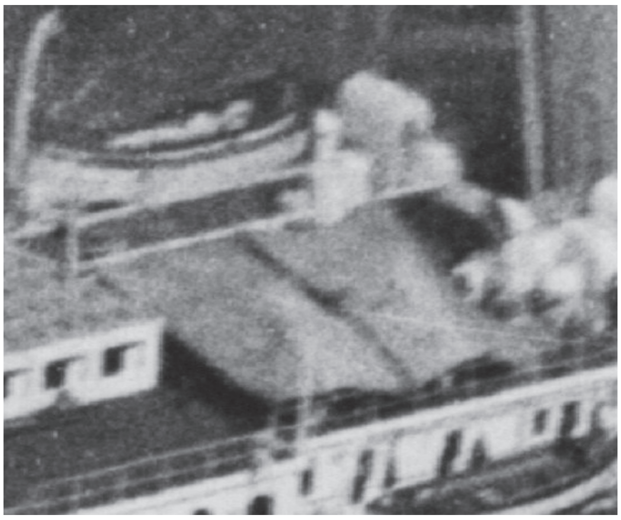


Fig. 12-30 **Rafter for Swing on A Deck** – *Olympic*'s after A Deck. At top, an awning rafter connected from the Boat Deck to the mainmast. There were two eye bolts fitted through the rafter's bottom edge to carry a swing for the passengers' recreation. *(Daniel Klistorner collection)*





Above and right Fig. 12-31 **Awning Rafter on Officers' Quarters Deckhouse Roof** – At left, an image of *Olympic* in port, showing the awning in use forward of the skylight dome cover on the Officers' Quarters deckhouse. At right, *Titanic*'s awning rafter, seen mounted to the top of a Gibb's extractor ventilation head. *(Both images authors' collection)*

Inside athwartship bulwarks aft of Bridge: 4ft 9in high, teak rail 7in x 3in.

Amidships steel bulwarks: 3ft 6in high, teak rail 7½in x 3in, running from frame 28F to frame 35A; stiffened and stayed at 4ft 6in intervals.

Boat Deck Railings

3ft 6in high, with stanchions spaced 4ft apart, riveted to 6in washboards, unless otherwise noted.

Tops of deckhouses on Boat Deck forward: (1) lower rail and iron-tube top rail.

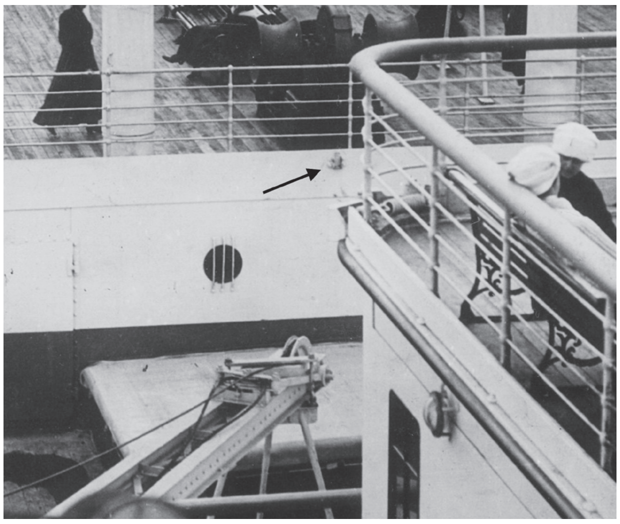
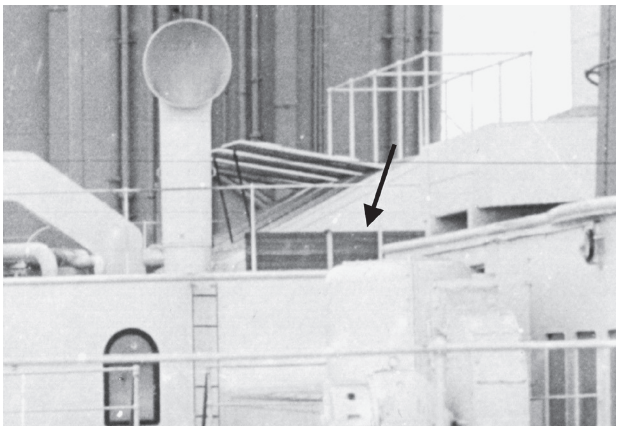


Fig. 12-32 **Rafter Bracket on Poop Deck** – An arrow indicates the awning rafter bracket attached to the wash plate of the forward end of the Poop Deck on *Titanic*. *(*Cork Examiner*/ Authors' collection)*

Fig. 12-33 **Mystery No.1** – The object or objects indicated by the arrow in this image of *Titanic* has created considerable debate among those who research these ships. While these objects have never been definitively identified, they appear to be a stack of teakwood boards standing on edge and clamped together. As it was common to see awning rafters over the engine casings on many steamships, including those built by Harland & Wolff, could these boards be stowed awning rafters, even though they are not painted white as was the usual practice? The lack of awning stanchions is not a disqualifier since the stanchions were normally portable. If these boards were used as awning rafters for the engine casing, it would certainly not be the first time that rafter boards, when not rigged, were stacked and attached to a railing or other shipboard fitting in the open.



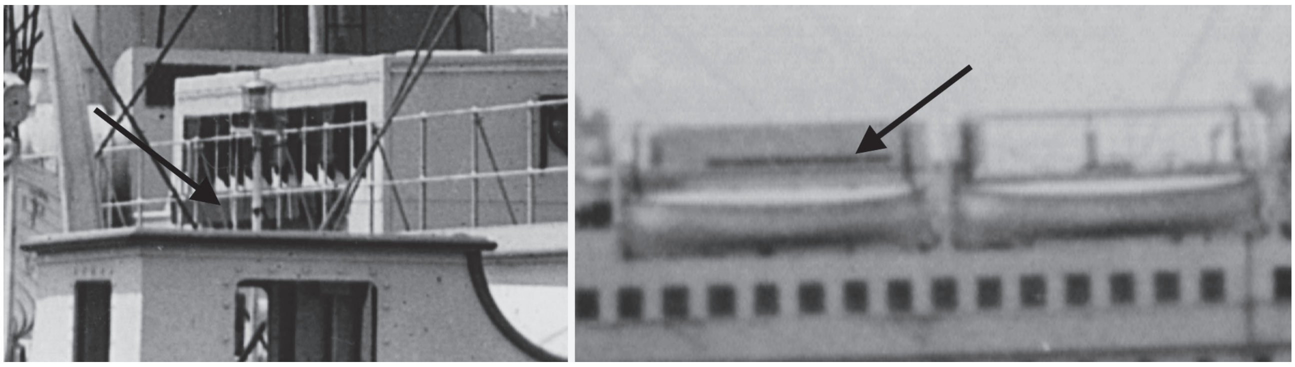


Fig. 12-34 **Mystery No.2** – As with the mystery boards aft of the engine casing, here, too, is another fitting that may be for a similar purpose. On *Olympic* (left) and *Titanic* (right), there were what appear to be dark-colored boxes fitted along the port and starboard sides of the dome cover over the forward First Class staircase. These 'boxes' appear to be unpainted teak boards placed upon brackets on each side. What appears to be a clamp can also be seen in the left-side photo. Were these, in fact, rafter boards for the awnings intended for the roof of the Officers' Quarters deckhouse? There are no signs of these on the wreck of *Titanic*, and photos of *Olympic* show these fittings to have been removed early in her career. These objects have yet to be positively identified, but they do fit the rafter profile. *(Both images authors' collection)*

Tops of No.3 Funnel casing and deckhouse, Tank Rooms, reciprocating engine casing and No.4 Funnel casing and deckhouse: single iron-tube top rail.

Promenade division barriers: (2) lower rails, teak top rail 6in x 2½in, stanchions fitted into deck grommets. Barriers had 3ft wide gates port and starboard, generally in the center of the promenades. Access warning signs fitted at each division.

Across after end of Boat Deck: (4) 4¾in-diameter lower rails, 6in x 3in teak top rail.

Single-bar railing fitted to the sides of the funnels at the intersections with the railings on the casings.

A DECK BULWARKS (MEASUREMENTS FROM TOP OF WOOD DECK TO TOP OF TEAK RAIL)

Forward steel bulwarks: 3ft 6in high; stayed at every stiffener; teak rail 7in x 3in athwartship and around to sides ending at frame 77F.

Side steel bulwarks: 3ft 6in high; teak rail 8in x 3in from frame 77F to frame leg at 72F before side screens; then from frame leg at 2F abaft side screens to frame 81A. Teak railing 6in x 3in aft of frame leg at frame 81A; stayed at every stiffener aft of frame 81A; rectangular wash port fitted port and starboard into the bulwark between frames 70F and 69F.

Vertically hinged access door 2ft 6in wide, port and starboard, in forward bulwarks in association with the leadsman's platforms.

A DECK RAILINGS

3ft 6in high, with stanchions spaced 4ft apart, riveted to 6in washboards unless otherwise noted.

Across after end of deck: (4) ⅛in diameter lower rails, teak top rail 6in x 3in.

B Deck Bulwarks (measurements from top of wood deck to top of teak rail)

Forward steel bulwark: 3ft 6in high, forward and around to frame 72F; teak rail around to sides ending at frame 80F: 8in x 3in; teak rail between frames 80F and 75F: 9in x 3in; bulwark stayed at every stiffener except in way of gangway doors; stays at the forward end fastened to the deck by tap bolts and grommets; stays at sides riveted to the inboard angle of the waterway channels; rectangular wash port fitted port and starboard into the bulwark between frames 74F and 73F.

Steel bulwarks aft of *à la carte* Restaurant and Café Parisien: 3ft 6in high, teak rail from midway between frames 76A and 77A to frame leg at frame 88A: 9in x 3in; teak rail from frame 88A to end at frame 99A: 7in x 3in; stayed at every stiffener aft of frame 95A.

Folding gangway door port and starboard in after bulwarks from frame 95A to just ahead of 92A, 10in wide.

B Deck Railings

3ft 6in high, with stanchions spaced 4ft apart, riveted to 6in washboards unless otherwise noted.

Railings at after end of deck: (4) ⅜in-diameter lower rails, teak top rail 6in x 3in. Barrier gates 3ft wide were fitted within railings at aft end of B Deck, port and starboard, also on the forward bulwark port side. Gates placed at the top landings of stairs from the forward and after Well Decks, and provided with mechanisms to secure but not lock them. Stairs[3] were iron and teak with brass treads, 2ft 6in wide, and portable.

Forecastle and Poop Deck Railings

Railings were 3ft 6in high, and portable in way of fairleads. Stanchions spaced 4ft apart and riveted to sheer plates at sides and to the wash plates at the deck ends athwartship. Rails consisted of (4) ⅜in-diameter lower rails (3 lower rails in the portable sections) and a 1⅜in-diameter iron-tube top rail, except for the railing athwartship at the after end of the Forecastle Deck, which had a fifth lower rail. Stairs to Forecastle and Poop Decks were iron and teak with brass treads, 2ft 6in wide, and portable.

Well Deck Bulwarks

Port and starboard bulwarks in Well Decks: top edges stiffened by steel flat-section bar, 3½in x ¾in, riveted outside and 3½in x 1¼in cope inside.

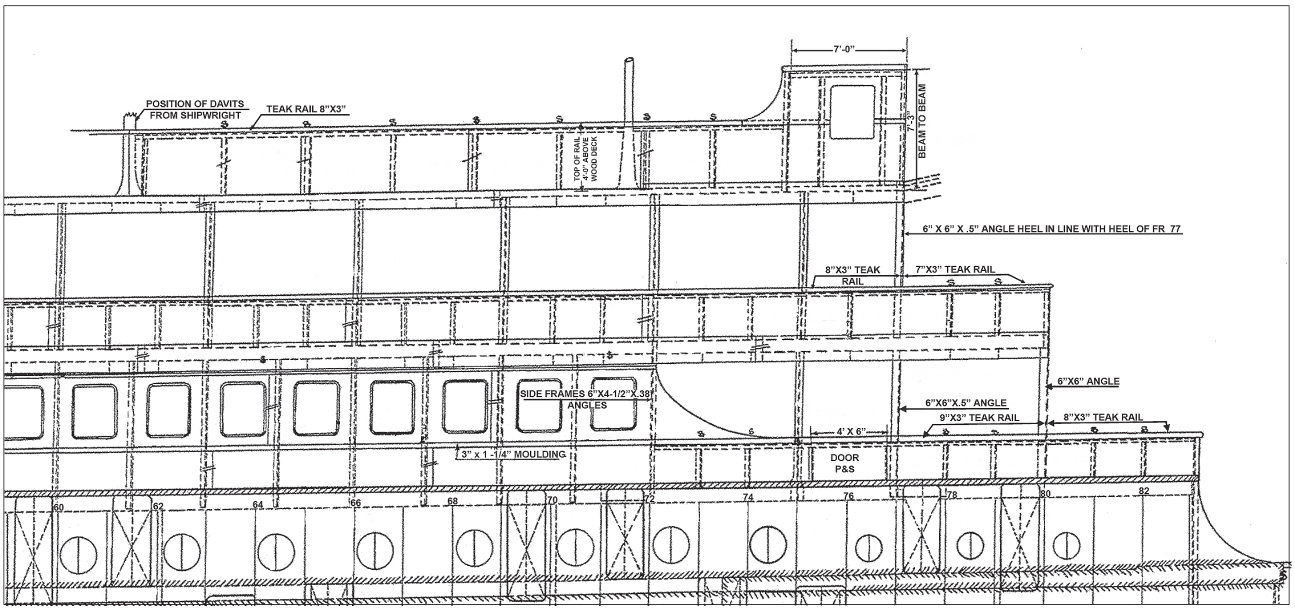

POSITION OF DAVITS FROM SHIPWRIGHT
TEAK RAIL 8"X3"
7'-0"
7'-3"
BEAM TO BEAM
TOP OF RAIL 4'-0" ABOVE WOOD DECK
6" X 6" X .5" ANGLE HEEL IN LINE WITH HEEL OF FR 77
8"X3" TEAK RAIL
7"X3" TEAK RAIL
6"X6" ANGLE
6"X6"X.5" ANGLE
9"X3" TEAK RAIL
8"X3" TEAK RAIL
SIDE FRAMES 6"X4-1/2"X.38 ANGLES
4' X 6"
3" x 1 -1/4" MOULDING
DOOR P&S
60
62
64
66
68
70
72
74
76
78
80
82

Fig. 12-35 **Forward A Deck Railings** – The railings at the forward end of the A Deck promenade were of different sizes. This illustration is provided to aid the reader in better understanding the transitions described in the text. *(Illustration by Bruce Beveridge based on original H&W plan)*

Folding gangway doors, forward Well Deck port and starboard: 14ft wide (forward), and 12ft 6in wide (aft).

Folding gangway doors, after Well Deck port and starboard: 12ft wide (forward), and 10ft 6in wide (aft).

Wash ports: 3ft x 1ft.

Notes

1. The term 'wash port' does not refer to washing decks, but to water washing over the deck (as in the decks being awash).
2. Many historians and modelers assume the teak rails of the *Olympic*-class liners to have been dark brown like oiled or varnished teak. However, there are many photographs which show the rails and deck chairs as light in color as the pine decking. This would indicate that the rails on *Titanic* were not dark brown, but much lighter, possibly being untreated teak. The teak margin planks around the deckhouses were natural, and they appear only slightly darker than their pine counterparts in black-and-white photographs.
3. Stairs such as these were properly termed 'ladders' or 'deck ladders.' These are covered in greater detail in Chapter 2 of Volume 2.

Chapter 13

Funnels, Masts and Rigging

To anyone unfamiliar with ships, *Titanic*'s rigging presents a complicated picture, especially with the profusion of cargo-handling lines in place in port. However, making sense of the various lines is not difficult if their purpose is understood. In addition, lines for cargo handling were normally stowed at sea and this simplifies the picture further.[1]

Titanic's rigging, as with any ship, can be divided into two categories, 'standing rigging' and 'running rigging'. Standing rigging includes lines that were fixed (attached) at both ends. The majority of this category includes lines that were used to support the masts and funnels. On land these would be termed 'guy wires;' on a ship they are termed 'stays' and 'shrouds'.

The term 'stay' normally refers to a supporting line of rigging that is in line with the centerline of the ship. Stays can be divided further into forestays and backstays, depending on whether they ran fore or aft, respectively, from the mast or funnel. (The term 'backstay' also applied to rigging that ran both aft and outward from the mast.) The term 'shroud' traditionally refers to any supporting line rigged athwartships, or out toward the sides of the ship, although all the lines supporting the funnels were considered shrouds. Much of the standing rigging, being permanent, was fastened to pad eyes in the deck or eye plates riveted directly to the sheer strake or bulwarks.

Galvanized steel wire rope, abbreviated 'GSWR' on rigging plans, was used for all stays and shrouds. (The designation 'GSWR' will also be used throughout the remainder of this chapter to refer to wire rope of this type.) Wire rope was immensely strong compared to manila or hemp, and provided far greater strength while permitting a significant reduction in diameter. At one time all ropes were made of natural (plant) fiber which was teased out and spun into suitable form by hand or machine. Natural-fiber rope includes hemp, manila, coir and sisal, but since the introduction of iron and particularly mild steel in shipbuilding, rope made of this latter material rapidly superseded all others, even for lines that have to run through pulleys or around winch drums. Steel, when drawn into wire, can be twisted into rope identical in appearance to rope made of natural fibers, albeit with far greater strength and durability. Wire ropes were made in various lengths; other ropes were generally made in lengths of about 112 fathoms.

'Running rigging' includes all lines that were hauled on: that is, used to hoist or lower cargo, men, flags, or anything else. In the days of sail, the running rigging of a fully rigged ship was very complex and included many lines not seen on fully engine-powered ships: for example, halyards for hoisting and lowering yards, sheets, tacks, and clew lines for trimming sails; braces for slewing the yards and lifts for squaring them. By the time of *Titanic*, the running rigging on a mast was comparatively simple and consisted chiefly, but not limited to, halyards for hoisting flags, gantlines, lines for hoisting and lowering cargo and the rigging required for working the mast derricks. Running rigging was typically belayed to the bases of stays, shrouds, or cleats located around the bulwarks and washboards, or to belaying pins.

Gantlines were rove through iron blocks on the masts and funnels. They were prominent on *Titanic*'s funnels and were used for rigging stages or 'bosun's chairs' when painting the funnels.

Lines such as these, and other lines that did not need to bear a significant load as did those used in cargo handling, were typically made of hemp or manila. Hemp rope, made from the stem fibers of the Hemp plant, is very strong and flexible and therefore very suitable for running through small blocks. Manila is made from fibers from the leaves of the Abaca plant. It is also strong and flexible and wears well, but unlike hemp rope is impervious to salt water.

MASTS

Titanic was rigged with two pole masts spaced about 600ft apart. These masts were made of steel, except for a 15ft teak section at the top of each mast. The tops of the masts stood approximately 205ft above the maximum load line, a height necessary to accommodate

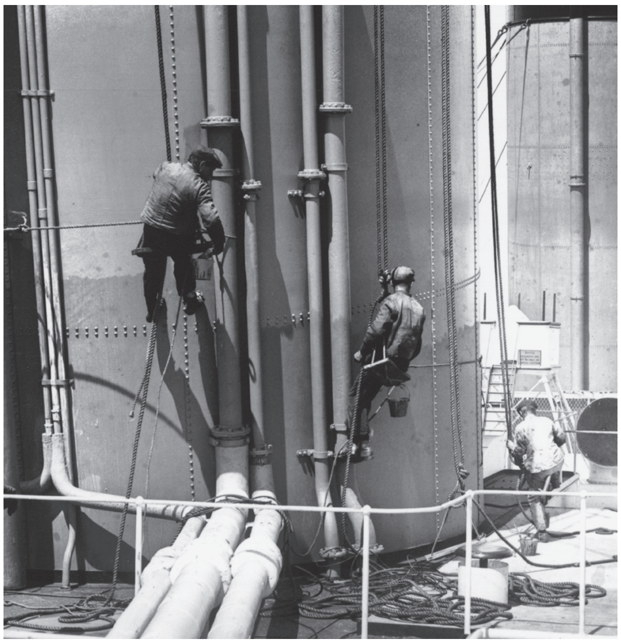


Fig. 13-1 **Painting Funnels, June 1911** – *Olympic*'s No.3 Funnel gets a touch-up in 1911. The painters are using bosun's chairs suspended from gantlines.

the Marconi aerial wires. This ensured that at its lowest point, the aerial would be at least 35ft above the top of the funnels and away from constant contact with the corrosive funnel gases. Unlike the masts in sailing vessels whose primary purpose was to carry sail, the primary purpose of *Titanic*'s masts was to provide support for a derrick and rigging for cargo handling, and secondarily, to carry the Marconi aerial aloft.

Titanic's masts, like those on most passenger liners of the period, were a departure from the masts on sailing vessels which were commonly constructed as distinct, independent sections termed lower masts, topmasts and upper topmasts. These were separate entities that were joined together in a number of different fashions, and the Board of Trade regulations specified the diameters, plating and strengthening of these separate mast pieces according to height. In the case of the *Olympic*-class ships, however, the lower masts and topmasts were made in one single section. To comply with regulations, the scantlings of the portion corresponding with the old lower mast classification were determined by the length from the heel to the ordinary height above the hound at which the masthead was situated. *Titanic*'s lower masts were made with three plates in the round and stiffened internally with angle bars, one being placed throughout the entire length of the mast at the middle of each breadth of plating. The angle bars increased in size with the increase in the mast's length. The plating was lapped at both the butts and edges in the 'in-and-out' fashion and double-riveted. Doublers were placed around the plating where necessary. The rivets used were pan-heads, countersunk and chipped flush on the outside. Each

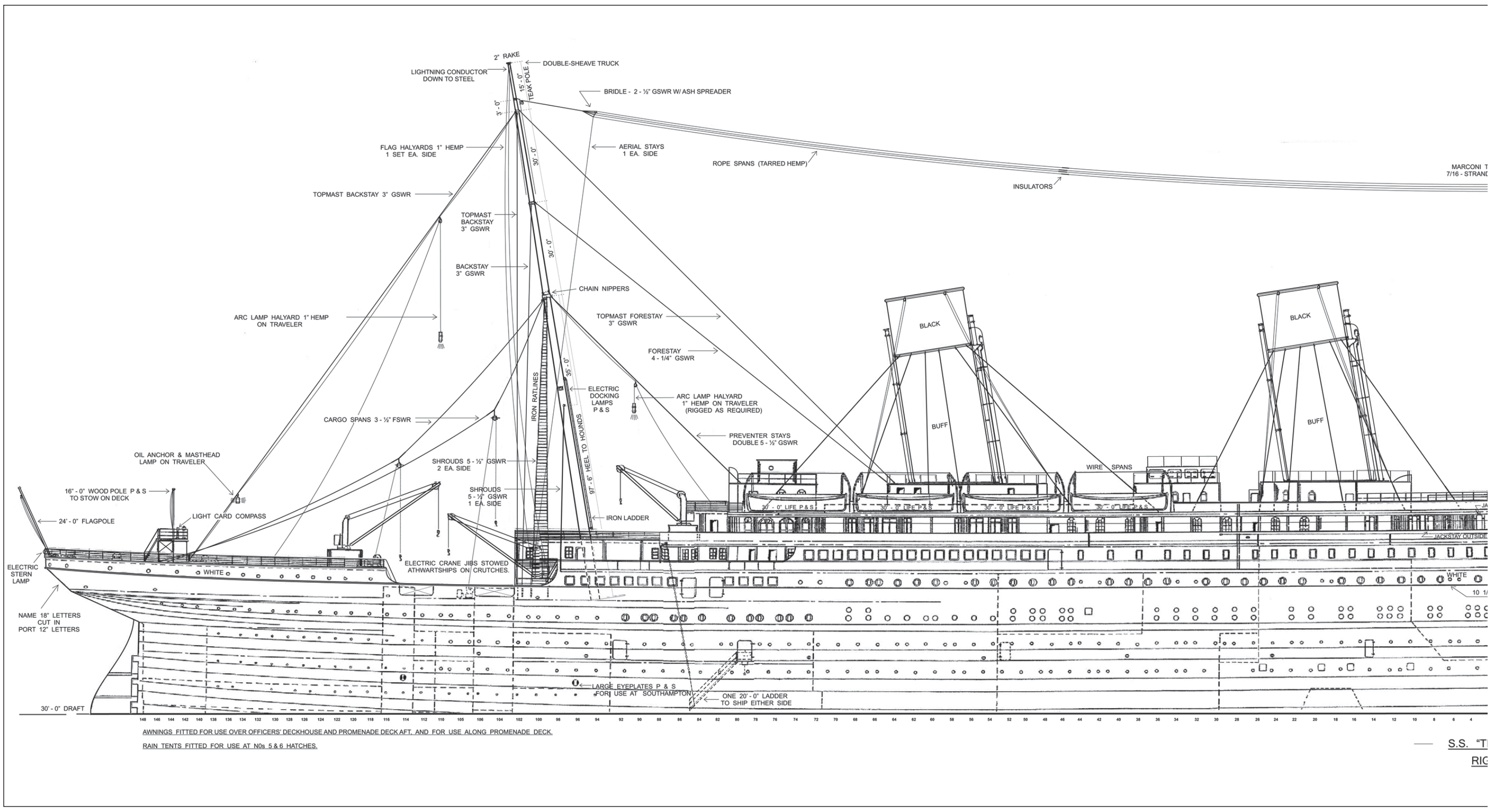

2" RAKE
DOUBLE-SHEAVE TRUCK
LIGHTNING CONDUCTOR DOWN TO STEEL
15' - 0" TEAK POLE
3' - 0"
BRIDLE - 2 - ½" GSWR W/ ASH SPREADER
FLAG HALYARDS 1" HEMP 1 SET EA. SIDE
AERIAL STAYS 1 EA. SIDE
ROPE SPANS (TARRED HEMP)
INSULATORS
MARCONI T
7/16 - STRAND
30' - 0"
TOPMAST BACKSTAY 3" GSWR
TOPMAST BACKSTAY 3" GSWR
BACKSTAY 3" GSWR
30' - 0"
CHAIN NIPPERS
ARC LAMP HALYARD 1" HEMP ON TRAVELER
TOPMAST FORESTAY 3" GSWR
FORESTAY 4 - 1/4" GSWR
35' - 0"
ELECTRIC DOCKING LAMPS P & S
ARC LAMP HALYARD 1" HEMP ON TRAVELER (RIGGED AS REQUIRED)
IRON RATLINES
CARGO SPANS 3 - ½" FSWR
PREVENTER STAYS DOUBLE 5 - ½" GSWR
97' - 6" HEEL TO HOUNDS
OIL ANCHOR & MASTHEAD LAMP ON TRAVELER
SHROUDS 5 - ½" GSWR 2 EA. SIDE
SHROUDS 5 - ½" GSWR 1 EA. SIDE
16" - 0" WOOD POLE P & S TO STOW ON DECK
24' - 0" FLAGPOLE
LIGHT CARD COMPASS
IRON LADDER
BLACK
BUFF
BLACK
BUFF
WIRE SPANS
30' - 0" LIFE P & S
30' - 0" LIFE P & S
30' - 0" LIFE P & S
30' - 0" LIFE P & S
30' - 0" LIFE P & S
JACKSTAY OUTSIDE
ELECTRIC STERN LAMP
WHITE
ELECTRIC CRANE JIBS STOWED ATHWARTSHIPS ON CRUTCHES.
WHITE
NAME 18" LETTERS CUT IN PORT 12" LETTERS
LARGE EYEPLATES P & S FOR USE AT SOUTHAMPTON
ONE 20' - 0" LADDER TO SHIP EITHER SIDE
30' - 0" DRAFT
AWNINGS FITTED FOR USE OVER OFFICERS' DECKHOUSE AND PROMENADE DECK AFT. AND FOR USE ALONG PROMENADE DECK.
RAIN TENTS FITTED FOR USE AT N0s 5 & 6 HATCHES.
S.S. "T
RIG

Fig. 13-2 **Diagram of *Titanic*'s Rigging.** *(Drawn by Art Braunschweiger based on original H&W Rigging Plan)*

mast had a diameter of 36in as measured at the step of the derrick, or at about 8ft above the deck.

With regard to *Titanic*, the term 'topmast' applied to that portion of the mast between the lower hounds and the base of the teak pole atop each mast. The topmast had two plates in the round that were not stiffened with angle bars. The laps of the edges were single-riveted. The butts were connected by treble-riveted straps, which were fitted inside in order that the mast's outer surface remained smooth. As with the funnels, the masts had an aft rake of 2in per ft.

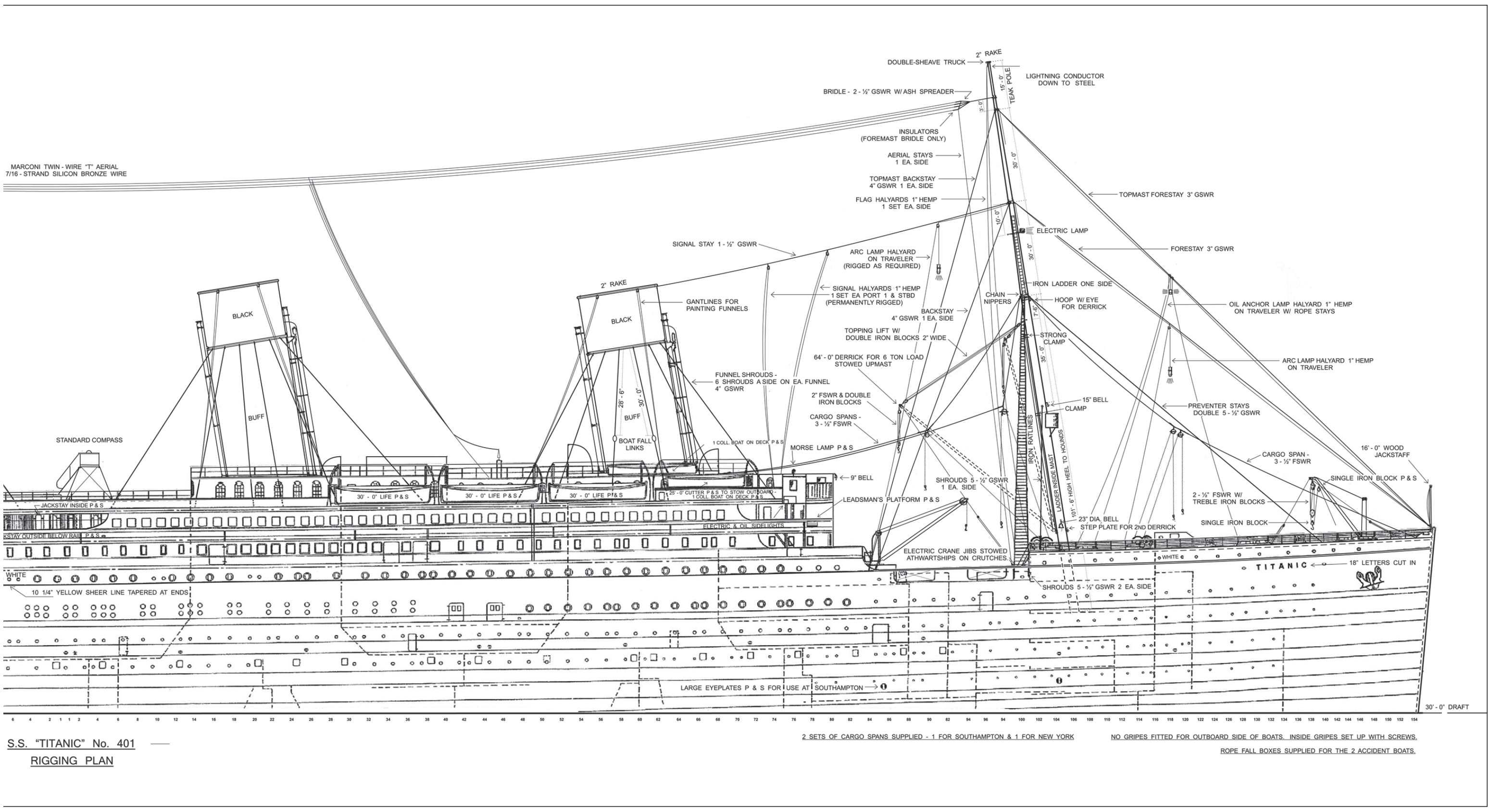
The masts were securely fixed into the deck and were supported by means of steel wire stays and shrouds. A mast-hole and wedging was fitted at the uppermost deck from which the masts exited the ship. A bulb-angle ring approximately 4in greater in diameter than the masts was riveted to the deck-plate, the plating of which was doubled in this area. When the mast was shipped in place, it was tightly wedged against the ring with hardwood. A stout plate riveted to the beams united it to the side stringers and distributed the stresses communicated from the mast through the wedging. Above the deck the wedging was neatly rounded, and a doubled canvas cover, or 'mast coat', was bound to the masts and over the ring to prevent leakage of water into the space below.

The doubling of the masts at the deck was to provide extra strength and to compensate for corrosion and pitting which took place in way of the wedging due to the steel of the masts being inaccessible at that point except when the vessel was under special survey.

The heels of the masts were supported on strong stools. Tremendous downward pressure was transferred to the masts through the rigging; if due provision were not made to resist these forces, the masts would have eventually been forced downward, causing the rigging to slacken and to become useless as a support against bending or swaying. For wedging purposes, a ring was fitted on the plates around the mast-heel; to keep the masts from turning, an angle or tee-lug, riveted to the deck plate, was fitted through the bottom of the mast. The mast-heel plating was doubled for a minimum distance of 4ft from the bottom to provide extra strength.

The rigging of both masts was attached to the brass hounds by eyelets fastened on their faces pointing fore, aft, starboard and port. The exception to this was a set of 5½in-circumference (1¾in-diameter) GSWR backstays fitted to the foremast, one to port and one to starboard, 47ft 6in above the deck, with a corresponding set on the mainmast 53ft 6in above the locations on B Deck where the lines were anchored to the bulwarks. On the mast, these backstays were shackled to a pad eye riveted directly to the mast plating.

The standing rigging of the masts was attached to the decks via turnbuckles, more properly termed 'rigging


DOUBLE-SHEAVE TRUCK
2" RAKE
LIGHTNING CONDUCTOR DOWN TO STEEL
15' - 0" TEAK POLE
BRIDLE - 2 - ½" GSWR W/ ASH SPREADER
3' - 0"
INSULATORS (FOREMAST BRIDLE ONLY)
AERIAL STAYS 1 EA. SIDE
30' - 0"
TOPMAST BACKSTAY 4" GSWR 1 EA. SIDE
FLAG HALYARDS 1" HEMP 1 SET EA. SIDE
TOPMAST FORESTAY 3" GSWR
10' - 0"
ELECTRIC LAMP
MARCONI TWIN - WIRE "T" AERIAL 7/16 - STRAND SILICON BRONZE WIRE
SIGNAL STAY 1 - ½" GSWR
ARC LAMP HALYARD ON TRAVELER (RIGGED AS REQUIRED)
FORESTAY 3" GSWR
30' - 0"
2" RAKE
SIGNAL HALYARDS 1" HEMP 1 SET EA PORT 1 & STBD (PERMANENTLY RIGGED)
IRON LADDER ONE SIDE
GANTLINES FOR PAINTING FUNNELS
CHAIN NIPPERS
HOOP W/ EYE FOR DERRICK
OIL ANCHOR LAMP HALYARD 1" HEMP ON TRAVELER W/ ROPE STAYS
BLACK
BLACK
BACKSTAY 4" GSWR 1 EA. SIDE
7' - 6"
TOPPING LIFT W/ DOUBLE IRON BLOCKS 2" WIDE
STRONG CLAMP
64' - 0" DERRICK FOR 6 TON LOAD STOWED UPMAST
35' - 0"
ARC LAMP HALYARD 1" HEMP ON TRAVELER
FUNNEL SHROUDS - 6 SHROUDS A SIDE ON EA. FUNNEL 4" GSWR
2" FSWR & DOUBLE IRON BLOCKS
15" BELL
CLAMP
28' - 6"
30' - 0"
BUFF
BUFF
PREVENTER STAYS DOUBLE 5 - ½" GSWR
CARGO SPANS - 3 - ½" FSWR
STANDARD COMPASS
BOAT FALL LINKS
1 COLL. BOAT ON DECK P & S
MORSE LAMP P & S
IRON RATLINES
LADDER INSIDE MAST
101' - 6" HIGH HEEL TO HOUNDS
16' - 0" WOOD JACKSTAFF
CARGO SPAN - 3 - ½" FSWR
9" BELL
SHROUDS 5 - ½" GSWR 1 EA. SIDE
SINGLE IRON BLOCK P & S
30' - 0" LIFE P & S
30' - 0" LIFE P & S
30' - 0" LIFE P & S
25' - 0" CUTTER P & S TO STOW OUTBOARD - 1 COLL. BOAT ON DECK P & S
LEADSMAN'S PLATFORM P & S
2 - ½" FSWR W/ TREBLE IRON BLOCKS
JACKSTAY INSIDE P & S
ELECTRIC & OIL SIDELIGHTS
23" DIA. BELL STEP PLATE FOR 2ND DERRICK
SINGLE IRON BLOCK
JACKSTAY OUTSIDE BELOW RAIL P & S
ELECTRIC CRANE JIBS STOWED ATHWARTSHIPS ON CRUTCHES.
WHITE
WHITE
TITANIC
18" LETTERS CUT IN
10 1/4" YELLOW SHEER LINE TAPERED AT ENDS
SHROUDS 5 - ½" GSWR 2 EA. SIDE
LARGE EYEPLATES P & S FOR USE AT SOUTHAMPTON
30' - 0" DRAFT
S.S. "TITANIC" No. 401
RIGGING PLAN
2 SETS OF CARGO SPANS SUPPLIED - 1 FOR SOUTHAMPTON & 1 FOR NEW YORK
NO GRIPES FITTED FOR OUTBOARD SIDE OF BOATS. INSIDE GRIPES SET UP WITH SCREWS.
ROPE FALL BOXES SUPPLIED FOR THE 2 ACCIDENT BOATS.

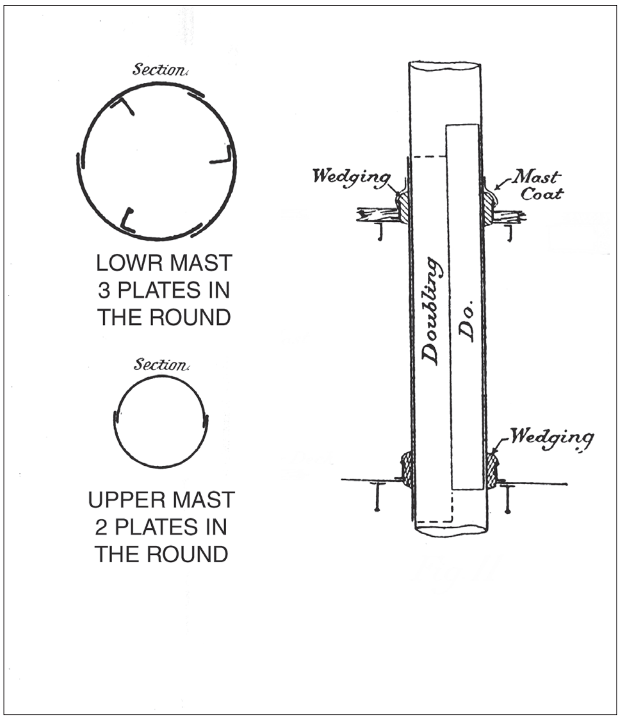

Section.
LOWR MAST
3 PLATES IN
THE ROUND
Section.
UPPER MAST
2 PLATES IN
THE ROUND
Wedging
Mast Coat
Doubling
Do.
Wedging

Fig. 13-3 **Mast Drawing** – Sectional views through a typical steel mast, showing the manner in which the plate strakes were lapped and internally reinforced, and also the manner in which a steel mast was fitted through the surrounding decks. *(*Practical Shipbuilding*/Authors' collection)*

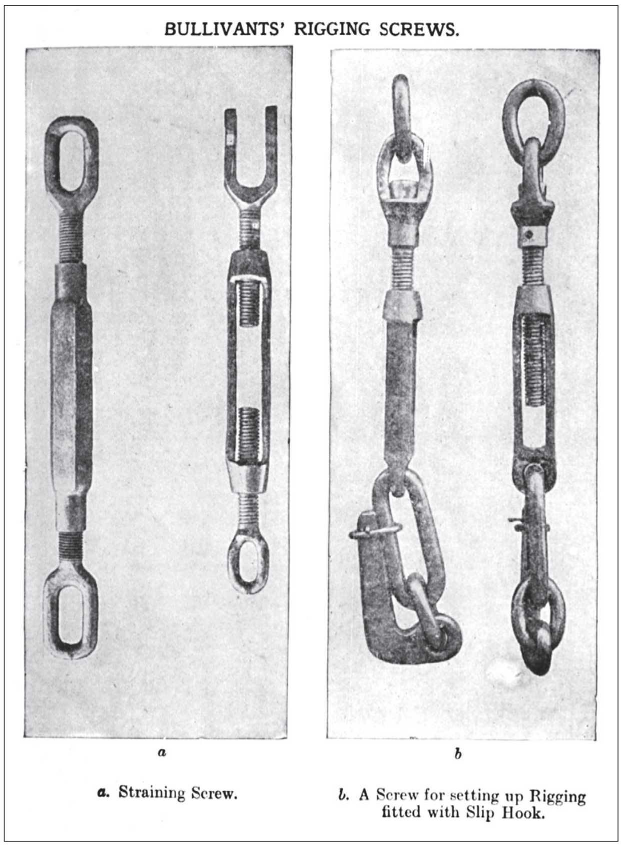

BULLIVANTS' RIGGING SCREWS.
a
b
a. Straining Screw.
b. A Screw for setting up Rigging fitted with Slip Hook.

Fig. 13-5 **Bullivant Rigging Screws** – (a) shows a straining screw for tightening up; (b) shows a screw for setting up rigging, fitted with a slip hook, as made by Bullivant & Co.

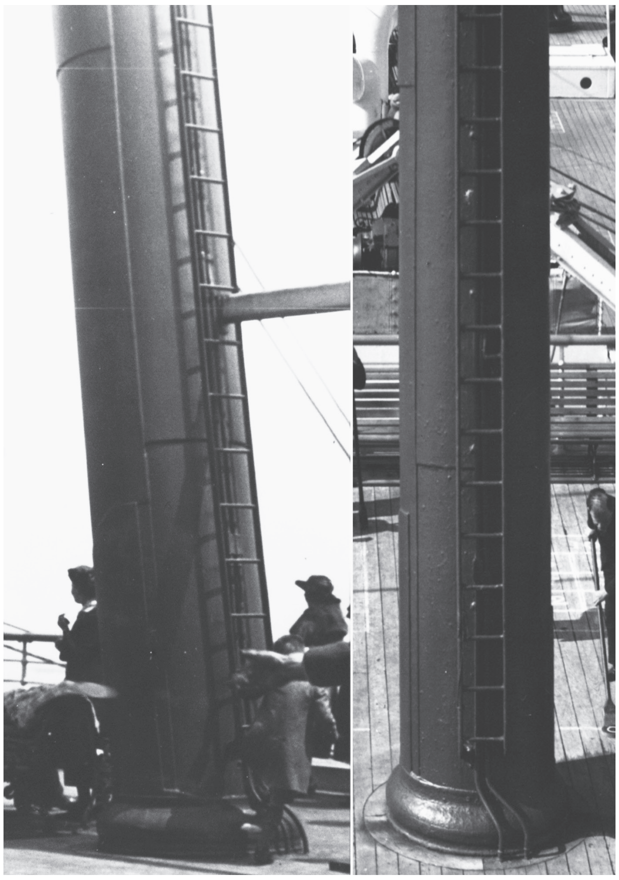


Fig. 13-4 **Mast on *Olympic*** – Two views of *Olympic*'s mainmast, showing the canvas 'mast coat' and collar at deck level. The horizontal wooden beam seen in the photo to the left is an awning rafter.

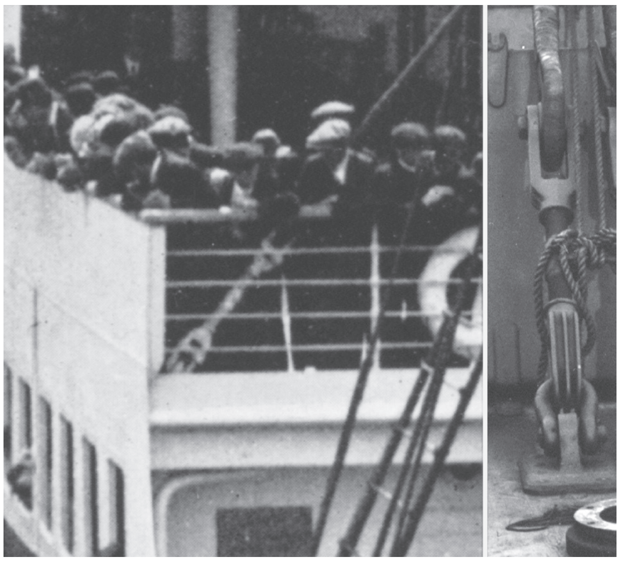


Fig. 13-6 **Rigging Screws** – Two examples of rigging screws used on *Olympic*.

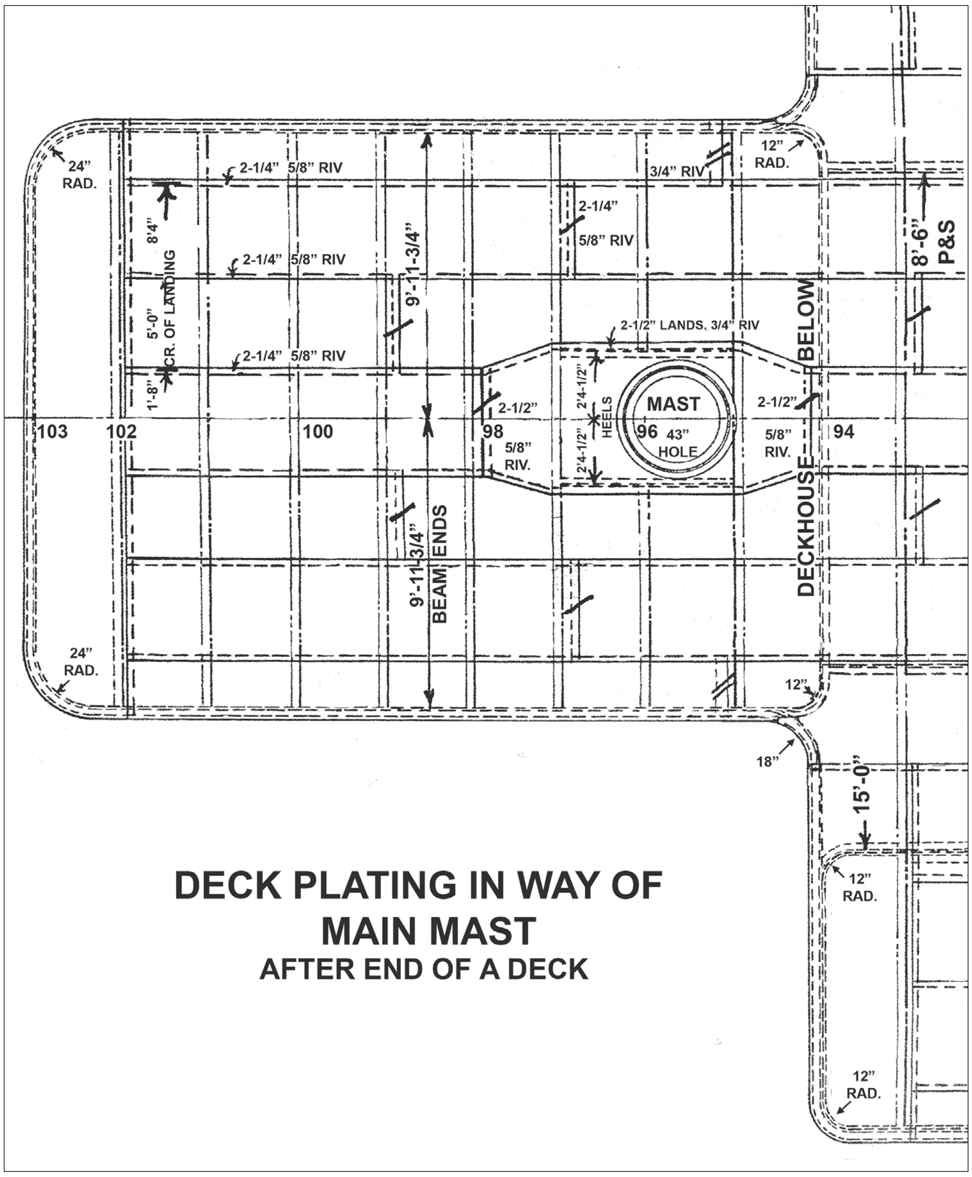

24" RAD.
2-1/4" 5/8" RIV
3/4" RIV
12" RAD.
2-1/4"
5/8" RIV
8'4"
5'-0"
CR. OF LANDING
1'-8"
9'-11-3/4"
8'-6" P&S
2-1/2" LANDS, 3/4" RIV
BELOW
DECKHOUSE
2-1/2"
2'4-1/2"
HEELS
MAST
43" HOLE
5/8" RIV.
103
102
100
98
96
94
BEAM ENDS
24" RAD.
12"
18"
15'-0"
12" RAD.
DECK PLATING IN WAY OF MAIN MAST
AFTER END OF A DECK

Fig. 13-7 **Plating in Way of Mast** – Plan of the deck beams and plating in the area of the main mast at A Deck. *(Illustration by Bruce Beveridge based on original Promenade Deck iron plan by H&W)*

screws'. A rigging screw consisted of two eyebolts, one being reverse threaded, attached in the center by a threaded tube.

The tube contained a hole in the center through which a bar or spanner could be inserted to turn the tube and tighten the rigging. Where the rigging attached to the steel decking, strong pad eyes and shackles were used. In the case of the athwartship rigging, eye plates were used instead as this rigging was attached to the sheer strakes, or at the bases of the bulwarks and channel plates. All steel wire rigging was fitted with the usual thimbles and seizing at the ends common with steel wire rigging of the period.

Foremast

The foremast was stepped at D Deck. It had a diameter of 36in at the bottom and terminated in a 15ft teak pole mounted at the top. The foremast was about 157ft 6in in length from the Forecastle Deck to the teak top head, 176ft 6in heel-to-head, and 101ft 6in heel-to-hound. An iron ladder was mounted to the starboard side of the mast just above the bottom hound to provide access to the navigational light located 102ft 6in up the mast from the Forecastle Deck.

The Crow's-nest, which was attached to the masthead, consisted of a thin, sheet-steel cage provided with a portable telephone inside and a 15in-diameter alarm bell

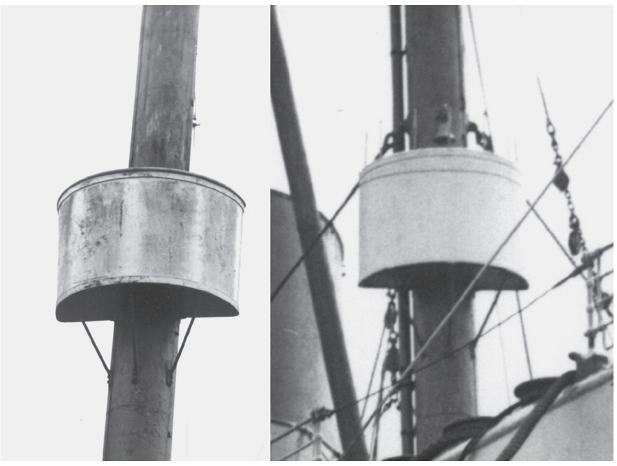


Fig. 13-8 **Crow's-nest on *Oceanic*** – Two examples of a typical Harland & Wolff crow's-nest. This was a common design used on many of their ships. The photo to left is the *Oceanic* of 1899, and to right is *Olympic* from later in her career. In the image to right, the vertical metal stanchions along the front of the crow's-nest were used for securing a canvas weather screen. *(H&W/Authors' collection)*

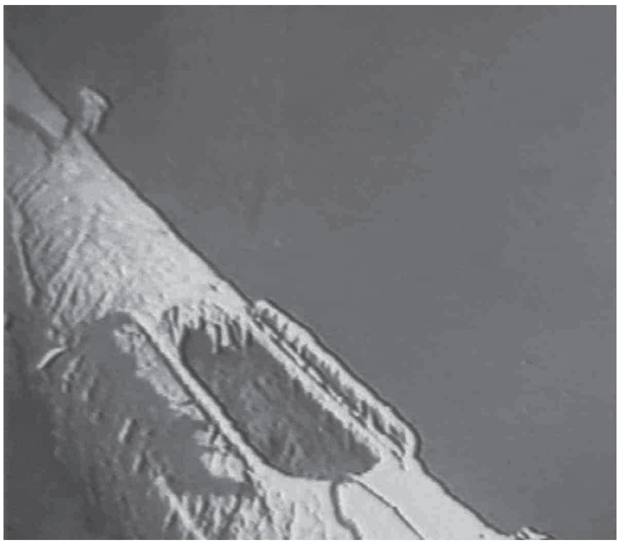


Fig. 13-9 **Access to Crow's-nest from Mast** – The crow's-nest was accessed by climbing a ladder inside the mast from C Deck and entering the crow's-nest through this opening, photographed on *Titanic*'s wreck. *(Bernhard Funk collection)*

mounted overhead. Stanchions were fitted around the bulwarks of the cage to support a canvas weather shield. The Crow's-nest was accessed through an opening in the forward face of the mast on C Deck; inside was a ladder mounted internally to the mast.

The bottom hound of the foremast was mounted 82ft 6in from the Forecastle Deck and 7ft 6in above the end of the derrick when in its stowed position. It was at this location that the ratline shrouds were fitted, both port and starboard. These shrouds were of 5½in-circumference (1¾in-diameter) GSWR. The bases of the shrouds were shackled to heavy eye plates mounted along the forward Well Deck bulwarks. Attached to the forward eyelets of the bottom hound were two preventer stays, or 'preventers', running parallel to each other and connected to the Forecastle Deck just aft of the center anchor crane. These two cables were of 5½in-circumference (1¾in-diameter) GSWR, and had the purpose of countering the pull on the mast from the load on the cargo spans that would be rigged on the opposite side of the mast when in port. Unlike the preventers in sailing ships, which were rigged alongside existing stays for added support in extreme weather, *Titanic*'s preventers were rigged permanently. Immediately below the hound was a hoop with an eye for the derrick tackle. The after eyelet was used for cargo handling on the forward Well Deck.

The middle hound was mounted up the mast approximately 112ft 6in above the Forecastle Deck. To the fore eyelet was fastened a forestay of 4½in-circumference (1$^{7}/_{16}$in-diameter) GSWR. This stay attached to a turnbuckle mounted on the raised stem at the bow.

The port and starboard backstays were of 4in-circumference (1¼in-diameter) GSWR. They fastened to the heavy web plates in the aft corners of the forward Well Deck. To the aft eyelet on the hound was fastened a steel wire, the opposite end of which attached to an eye on the fore side of the top stiffening band on the No. 1 Funnel. This wire, called a signal stay, carried two iron blocks above the Navigating Bridge, rigged with halyards from the port and starboard sides of the Bridge for hoisting signal flags. When necessary, another iron block could be temporarily rigged to the signal stay forward of the signal halyards to rig an auxiliary halyard for an arc lamp over the Nos 2 and 3 Hatches.

The top hound was mounted up the mast 142ft 6in above the Forecastle Deck. The forward eyelet held

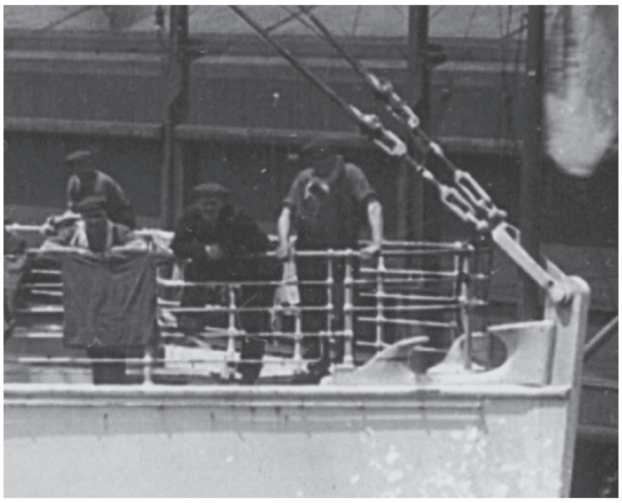


Fig. 13-10 **Raised Stem** – *Olympic*'s raised stem, seen here in 1911. The Shell Plating plan indicates this portion of the stem was 10in wide and 3in thick. Here, rigging screws can be seen once again. The castings suggesting the appearance of an anvil were fairleads for guiding various lines. *(Josha Inglis collection)*

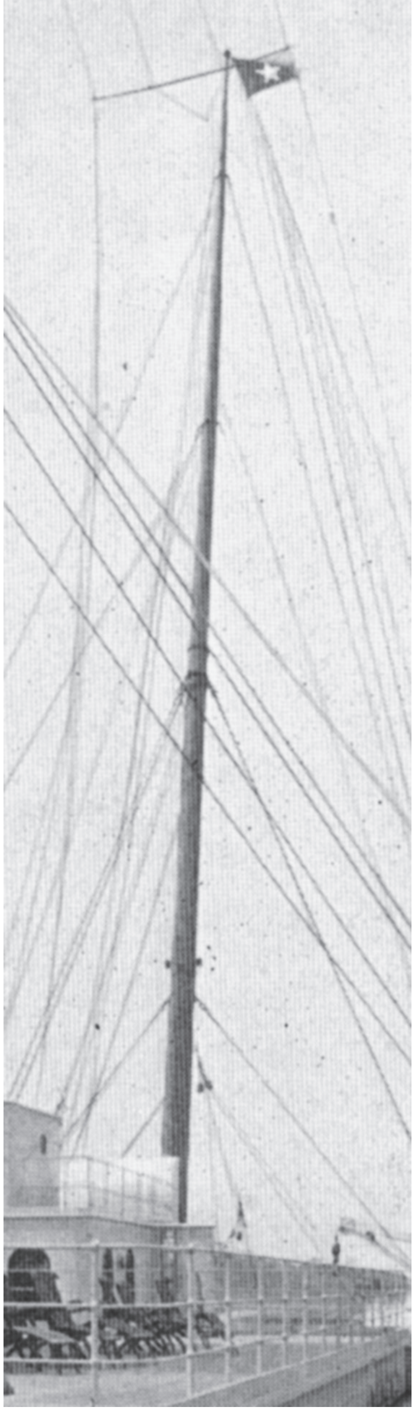


Fig. 13-11 **Mainmast** – *Olympic*'s mainmast, seen here sporting the White Star Line house flag.

a forestay of 3in-circumference (1$^{1}/_{32}$in-diameter) GSWR. The forestay attached to the turnbuckle at the stem just as the lower forestay did. The backstays were of 4in-circumference (1¼in-diameter) GSWR and again attached to the web plates in the aft corners of the forward Well Deck. The top hound was also the point where the teak topmast was attached. Located 2ft above the top hound was the connection ring for the bridle connected to the Marconi antenna spreader. The mast cap, or truck, at the top had two built-in sheaves for flag halyards. The lower ends of the flag halyards, when at sea, were tied off to the lower extremity of the ratlines.[2]

The lower of the two forestays was also used to rig an arc lamp above the No.1 Hatch when required. The arc lamp halyard, permanently rigged, was carried by an iron block attached to a traveler that ran along the stay. A separate line, permanently rigged to the traveler, ran parallel to the stay, up through a block at the mast and then down to the deck. By means of this line, the arc lamp halyard could be positioned at any point along the stay as required. An identical arrangement carried an iron block on the upper stay for use with an oil anchor lamp. The traveler for this block, however, also carried two additional lines that functioned as stays for the anchor lamp. Oil anchor lamps were constructed with two narrow cylindrical stay guides, one on each side of the lamp, through which separate lines ran and which, when the stays were tautly belayed on deck, functioned to prevent the lamp from swinging excessively and possibly extinguishing the flame. As with the arc lamp halyard, these lines were permanently rigged and belayed at the deck level when not in use.

On the aft side of the foremast, about 8ft above the deck, was mounted a 25in-diameter bell, a throwback to years past. On the last of the iron sailing ships there was an anchor windlass situated centrally beneath the Forecastle Deck; this was worked from the top of the Forecastle Deck by men walking around the capstan pushing bars to turn it. A bell located nearby was sounded rapidly to inform the captain that the anchor was aweigh, or sounded once for every shot (15 fathoms) of chain paid out or hauled in. With the advent of the telephone system, this practice of the past was retired and consequently *Titanic*'s bell was not used for this purpose unless there was a malfunction of the telephone system or unless there was another need for audible signals, such as was required at anchor during fog.

Mainmast

The after mast, correctly termed the 'mainmast', was stepped on C Deck. Like the foremast, it had a diameter of 36in at the bottom and terminated in a 15ft teak pole mounted at the top. The mainmast was 154ft 6in in length from A Deck to the teak top head, 172ft 6in heel-to-head, and 97ft 6in heel-to-hound.

The bottom hound of the mainmast was mounted to the mast 79ft 6in from A Deck and 35ft above the mast shrouds. Below the hound, and 49ft above A Deck, was a pair of docking lamps mounted to the mast plating port and starboard. The bottom hound was the top connection for ratline shrouds fitted port and starboard, these shrouds being of the same material and size as those on the foremast. The bases of the ladders were shackled to heavy eye plates mounted along the after Well Deck bulwarks. Attached to the forward eyelets of the bottom hound were two preventers, running parallel to each other and connected to the after end of the roof over the Second Class Entrance on the Boat Deck. These two preventers were of 5½in-circumference (1¾in-diameter) GSWR and served the same function as the preventers on the foremast. The after eyelet on the hound was used for cargo handling. Twin cargo spans were attached to the eyelet on the mast, leading to pad eyes just forward of the Docking Bridge on the Poop Deck. They were of 3½in-circumference (1⅜in-diameter) GSWR, rigged the same as the cargo spans for the forward Well Deck. The electric winches in the after Well Deck and the Poop Deck were used with the cargo runners here; these, along with the cargo rigging, are discussed in greater detail in Chapter 21 of this volume

The middle hound was mounted up the mast 109ft 6in above A Deck. On the forward eyelet was fastened one forestay of 4½in-circumference ($1^{7}/_{16}$in-diameter) GSWR. This stay attached to a rigging screw mounted on the aft side of the deckhouse roof beneath the No.4 Funnel. The port and starboard backstays were of 4in-circumference (1¼in-diameter) GSWR, fastened to eye plates riveted to the bulwarks at the forward corners of the after Well Deck.

The top hound was mounted to the mast 139ft 6in from A Deck. The forward eyelet accommodated a forestay of 3in-circumference ($1^{1}/_{32}$in-diameter) GSWR. The top forestay attached to a rigging screw on the No.4 Funnel deckhouse roof, abreast of the lower forestay. The backstays were of the same size and type as the forestays and attached to eye plates riveted to the bulwarks at the forward corners of the after Well Deck. A third stay of the same size and type fastened to the aft eye of the top hound and connected to a rigging screw on the Poop Deck, below the forward edge of the Docking Bridge.

As with the foremast, the mainmast's top hound was also the point in which the teak topmast was attached. Located 2ft above the top hound was the connection ring for an iron block. Through this block ran a line up from the deck and out a short distance to the bridle for the Marconi antenna spreader. By means of this tackle, the after end of the Marconi array could be lowered to the deck for maintenance.

The very top of the mast, termed the 'mast truck', accommodated two flag halyards in the same manner as the foremast. These were belayed to the base of the ratline shrouds in the same manner as the foremast halyards.

The after stay was also used for lamp halyards. Two iron blocks were permanently rigged to this stay on separate travelers in the same manner as the arc lamp halyard above the Forecastle Deck. In port, arc lamps could be hoisted aloft and positioned above the Nos 5 and 6 Hatches for illuminating the Well Deck while handling cargo. Either of these same iron blocks could be used to hoist an oil lamp aloft as a masthead light while underway. In 1912, according to the navigation regulations of the time, the display of an after masthead lamp was optional. If used, this lamp was to be higher than the light at the foremast. In this case the light on the mainmast stay would be hauled to the uppermost point on the stay, against the block, in order to position it as high as possible against the mast. If used for the required after anchor lamp, it would be displayed lower down on the stay, below the level of the anchor light suspended over the Forecastle Deck.

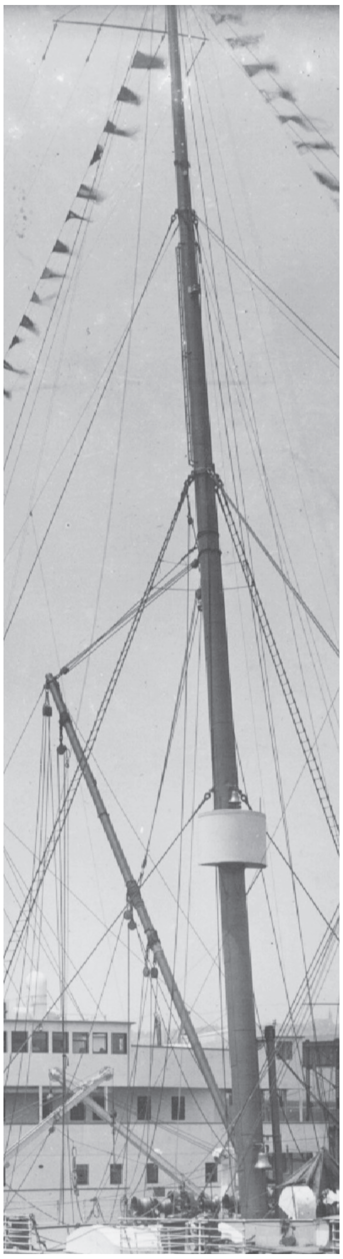


Fig. 13-12 **Foremast** – *Olympic*'s foremast *c.*1911, with the derrick deployed. *(Josha Inglis collection)*

Lightning conductors

Because the uppermost sections of the masts were wood and not steel, *Titanic* had lightning rods mounted to the tops of the teak poles.[3] The lightning rod, or 'air terminal', at each mast was provided with a lighting conductor to the steel below.

This consisted of a flexible wire rope of hard-drawn copper, about ⅜in overall diameter, which ran through the teakwood and into the mast. On earlier vessels with wood hulls and wood masts, a conductor had to be run from the truck at the top of the mast down to one of the stays and then along the stay to the deck; if the stays were of steel wire rope, insulators were required. Where the rigging met the deck, the conductor was left loose with sufficient slack to allow the end to trail in the water over the ship's side. A lead sinker was fastened to the end to keep the wire submerged.

In the case of a steel-hulled vessel such as *Titanic*, no conductor was required as the steel mast itself acted as a bridge to the hull, and as the hull effectively acted as an electrical conductor, no additional conductor was required to the water below.

The purpose of a lightning rod and conductor was to provide a safe pathway to ground, not to prevent lightning from contacting the ship. The term 'lightning strike' is erroneous, as lighting does not strike. Rather, it is the completion of an electrical pathway between opposite charges, with a violent release of energy. It is now known that a grounded lightning conductor and air terminal actually permits the opposite charges to meet and neutralize each other at a significant distance above the uppermost point of the conductor, rather than on the surface of or within the structure (or ship) as would occur without any such protection.

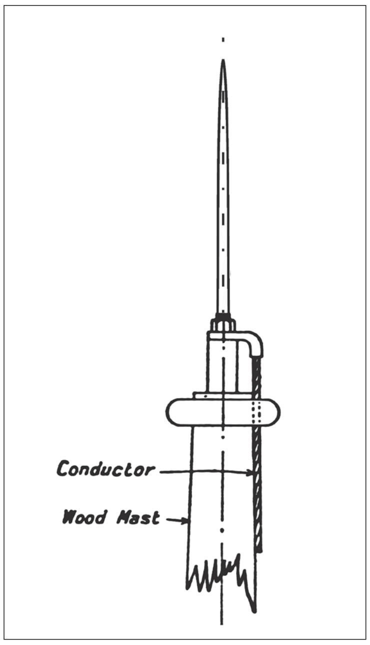


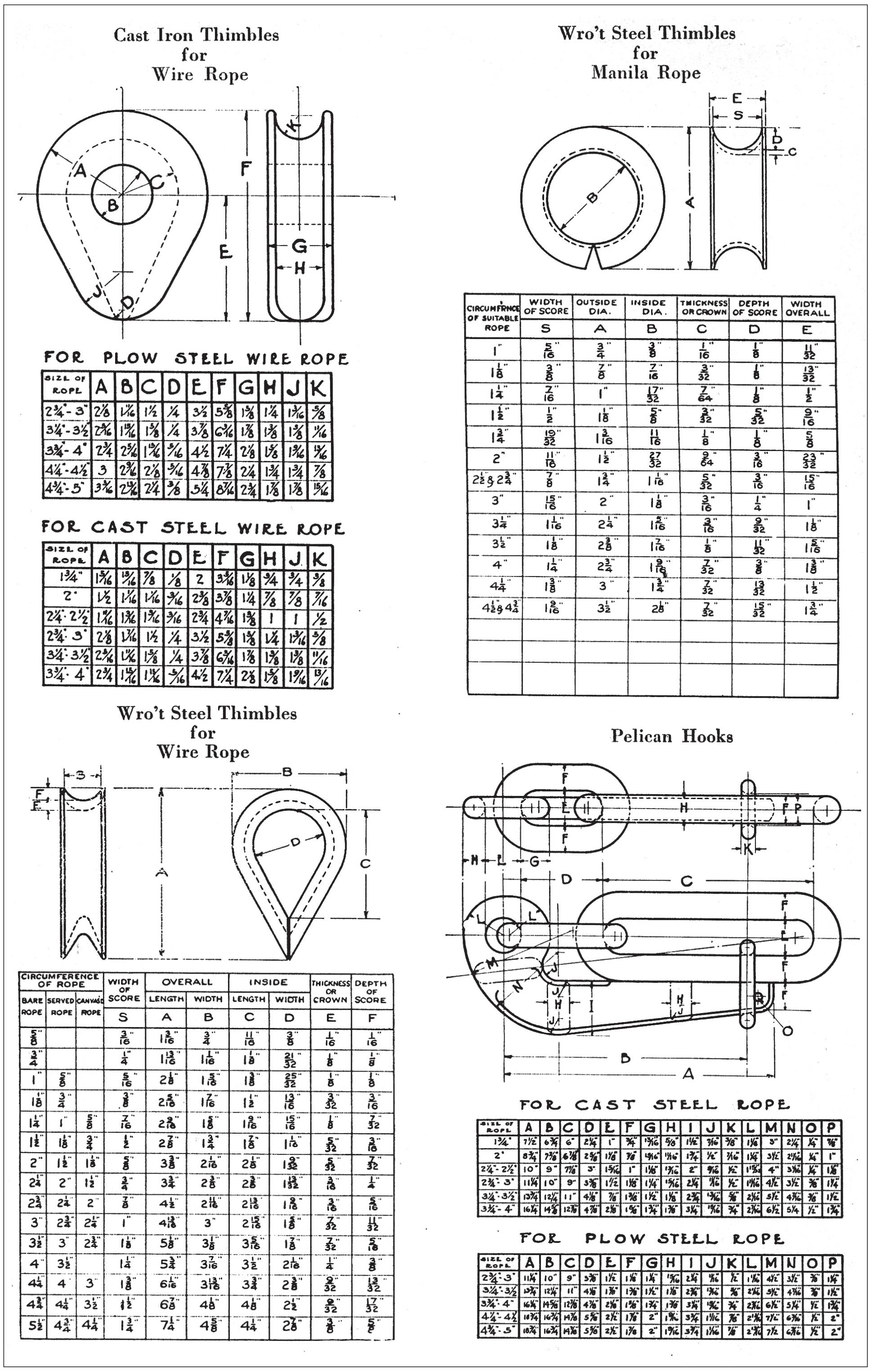
Fig. 13-13 **Lightning Conductor** – Illustration of a typical lightning conductor on top of a wooden top mast. These were apparently so thin that they have evaded detection in the authors' photos, but their presences are indicated on the rigging plans, and they were a much-needed protection against damage from lightning.

FUNNELS

One of the most visible features of the *Olympic*-class liners was their four massive funnels. The first three funnels were utilized to vent combustion gases from the boilers, with the fourth being called a 'dummy' although it was actually designed to function as a ventilator. This dummy funnel was also intended to enhance and give balance to the profile of the ship; at the same time, it also gave the impression of greater power and speed to those non-technical passengers who tended to judge and compare vessels by the number of funnels they carried.

In the first three funnels, the smoke and hot gases from the boiler furnaces were conveyed through passages called 'uptakes' to the funnels themselves. The first three funnels were actually divided into two distinct sections; the sections which surmounted the tops of the boiler casing and were visible from the exterior ship were simply referred to as the funnels, while the sections spanning the distance from the tops of the uptakes to the tops of the boiler casings were referred to as the 'lower funnels'.

Each of the first three funnels was fabricated as a double-wall structure throughout its entire height, with an 'outer funnel' enclosing the similarly shaped 'inner funnel', the latter being the actual flue that conveyed the byproducts of combustion to the atmosphere. The inner and outer funnels were stayed together by internal bracketing called 'distance pieces', and provision was made at the lowest level to admit air into the space between the two. In general, the cross-sectional area of an inner funnel was usually designed to be from one-seventh to one-tenth the area of the fire grates. Because the total fire grate area serviced by each of *Titanic*'s first three funnels was different, the dimensions for each inner funnel were also different, being sized to suit the total area of the fire grates beneath. Internally, the boiler uptakes were separated by baffle plates into individual trunks for each boiler which came together at the base of the lower funnel; these plates tended to encourage the gases to move in the same direction to the point where they mingled together. This avoided loss of draft within the individual branches of the uptakes due to variations in temperature or reversal of air currents. In certain cases, the baffles within the uptakes were extended to the full height of the inner funnels, terminating at the base of the upper funnels. A transverse division plate was fitted within each of the lower inner funnels to separate these into forward and after sections, each dedicated to the boiler room immediately beneath that section. This



Cast Iron Thimbles
for
Wire Rope

FOR PLOW STEEL WIRE ROPE

SIZE OF ROPE	A	B	C	D	E	F	G	H	J	K
2 3/4"-3"	2 1/8	1 11/16	1 1/2	1/4	3 1/2	5 5/8	1 5/8	1 1/4	1 3/16	5/8
3 1/4"-3 1/2"	2 9/16	1 15/16	1 5/8	1/4	3 7/8	6 3/16	1 7/8	1 3/8	1 3/8	11/16
3 3/4"-4"	2 3/4	2 5/16	1 13/16	5/16	4 1/2	7 1/4	2 1/8	1 5/8	1 9/16	13/16
4 1/4"-4 1/2"	3	2 9/16	2 1/8	5/16	4 7/8	7 7/8	2 1/4	1 3/4	1 3/4	7/8
4 3/4"-5"	3 3/16	2 13/16	2 1/4	3/8	5 1/4	8 7/16	2 3/4	1 7/8	1 7/8	15/16

FOR CAST STEEL WIRE ROPE

SIZE OF ROPE	A	B	C	D	E	F	G	H	J	K
1 3/4"	1 5/16	15/16	7/8	1/8	2	3 5/16	1 1/8	3/4	3/4	3/8
2"	1 1/2	1 1/16	1 1/16	3/16	2 3/8	3 7/8	1 1/4	7/8	7/8	7/16
2 1/4"-2 1/2"	1 11/16	1 3/16	1 5/16	3/16	2 3/4	4 7/16	1 3/8	1	1	1/2
2 3/4"-3"	2 1/8	1 7/16	1 1/2	1/4	3 1/2	5 5/8	1 5/8	1 1/4	1 3/16	5/8
3 1/4"-3 1/2"	2 9/16	1 11/16	1 5/8	1/4	3 7/8	6 3/16	1 7/8	1 3/8	1 3/8	11/16
3 3/4"-4"	2 3/4	1 15/16	1 13/16	5/16	4 1/2	7 1/4	2 1/8	1 5/8	1 9/16	13/16

Wro't Steel Thimbles
for
Manila Rope

CIRCUMFRNCE OF SUITABLE ROPE	WIDTH OF SCORE S	OUTSIDE DIA. A	INSIDE DIA. B	THICKNESS OR CROWN C	DEPTH OF SCORE D	WIDTH OVERALL E
1"	5/16"	3/4"	3/8"	1/16"	1/8"	11/32"
1 1/8"	3/8"	7/8"	7/16"	3/32"	1/8"	13/32"
1 1/4"	7/16"	1"	17/32"	7/64"	1/8"	1/2"
1 1/2"	1/2"	1 1/8"	5/8"	3/32"	5/32"	9/16"
1 3/4"	19/32"	1 3/16	11/16	1/8"	1/8"	5/8
2"	11/16"	1 1/2"	27/32	9/64"	3/16"	23/32"
2 1/2" & 2 3/4"	7/8"	1 3/4"	1 1/16"	5/32"	3/16"	15/16"
3"	15/16"	2"	1 1/8"	3/16"	1/4"	1"
3 1/4"	1 1/16"	2 1/4"	1 5/16"	3/16"	9/32"	1 1/8"
3 1/2"	1 1/8"	2 3/8"	1 7/16"	1/8"	11/32"	1 5/16"
4"	1 1/4"	2 3/4"	1 9/16"	7/32"	3/8"	1 3/8"
4 1/4"	1 3/8"	3"	1 3/4"	7/32"	13/32	1 1/2"
4 1/2" & 4 3/4"	1 9/16"	3 1/2"	2 1/8"	7/32"	15/32"	1 3/4"

Wro't Steel Thimbles
for
Wire Rope

CIRCUMFERENCE OF ROPE			WIDTH OF SCORE	OVERALL		INSIDE		THICKNESS OR CROWN	DEPTH OF SCORE
BARE ROPE	SERVED ROPE	CANVAS'D ROPE		LENGTH	WIDTH	LENGTH	WIDTH		
			S	A	B	C	D	E	F
5/8"			3/16"	1 3/16"	3/4"	11/16"	3/8"	1/16"	1/16"
3/4"			1/4"	1 13/16"	1 1/16"	1 1/8"	21/32"	1/8"	1/8"
1"	5/8"		5/16"	2 1/8"	1 5/16"	1 3/8"	25/32"	1/8"	1/8"
1 1/8"	3/4"		3/8"	2 5/16"	1 7/16"	1 1/2"	13/16"	3/32"	3/16"
1 1/4"	1"	5/8"	7/16"	2 9/16"	1 5/8"	1 9/16"	15/16"	1/8"	7/32"
1 1/2"	1 1/8"	3/4"	1/2"	2 7/8"	1 3/4"	1 7/8"	1 1/16"	5/32"	3/16"
2"	1 1/2"	1 1/8"	5/8"	3 3/8"	2 1/16"	2 1/8"	1 9/32	5/32"	7/32"
2 1/4"	2"	1 1/2"	3/4"	3 3/4"	2 3/8"	2 3/8"	1 13/32"	3/16"	1/4"
2 3/4"	2 1/4"	2"	7/8"	4 1/2"	2 11/16"	2 13/16"	1 9/16"	3/16"	5/16"
3"	2 3/4"	2 1/4"	1"	4 13/16"	3"	2 15/16"	1 5/8"	7/32"	11/32"
3 1/2"	3"	2 3/4"	1 1/8"	5 1/8"	3 1/8"	3 5/16"	1 7/8"	7/32"	5/16"
4"	3 1/2"		1 1/4"	5 3/4"	3 7/16"	3 1/2"	2 1/16"	1/4"	3/8"
4 1/4"	4"	3"	1 3/8"	6 1/16"	3 13/16"	3 3/4"	2 3/8"	9/32"	13/32"
4 3/4"	4 1/4"	3 1/2"	1 1/2"	6 7/8"	4 1/8"	4 1/8"	2 1/2"	9/32"	17/32"
5 1/2"	4 3/4"	4 1/4"	1 3/4"	7 1/4"	4 5/8"	4 1/4"	2 7/8"	3/8"	5/8"

Pelican Hooks

FOR CAST STEEL ROPE

SIZE OF ROPE	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1 3/4"	7 1/2"	6 3/4	6"	2 1/4	1"	3/4"	1 3/16"	5/8"	1 1/2"	3/16"	3/8"	1 1/8	3"	2 1/4	1/4	7/8
2"	8 3/4	7 3/8"	6 7/8	2 5/8"	1 1/8"	7/8"	1 9/16"	1 1/16"	1 3/4"	1/2"	7/16"	1 1/4"	3 1/2"	2 11/16	1/4"	1"
2 1/4"-2 1/2"	10"	9"	7 7/8"	3"	1 5/16	1"	1 1/8"	1 3/16"	2"	9/16"	1/2"	1 15/32	4"	3 3/16	1/4"	1 1/8"
2 3/4"-3"	11 1/4	10"	9"	3 3/8"	1 1/2	1 1/8"	1 1/4"	1 5/16	2 1/4"	11/16"	1/2"	1 11/16	4 1/2"	3 1/2"	3/8"	1 1/4"
3 1/4"-3 1/2"	13 3/4"	12 1/4	11"	4 1/8"	7/8"	1 3/8"	1 1/2"	1 1/8"	2 3/4"	1 3/16"	5/8"	2 1/16	5 1/2"	4 3/16	3/8"	1 1/2"
3 3/4"-4"	16 1/4	14 5/8	12 7/8"	4 7/8"	2 1/8"	1 5/8"	1 3/4"	1 7/8"	3 1/4"	1 5/16	3/4"	2 3/16	6 1/2	5 1/4	1/2"	1 3/4"

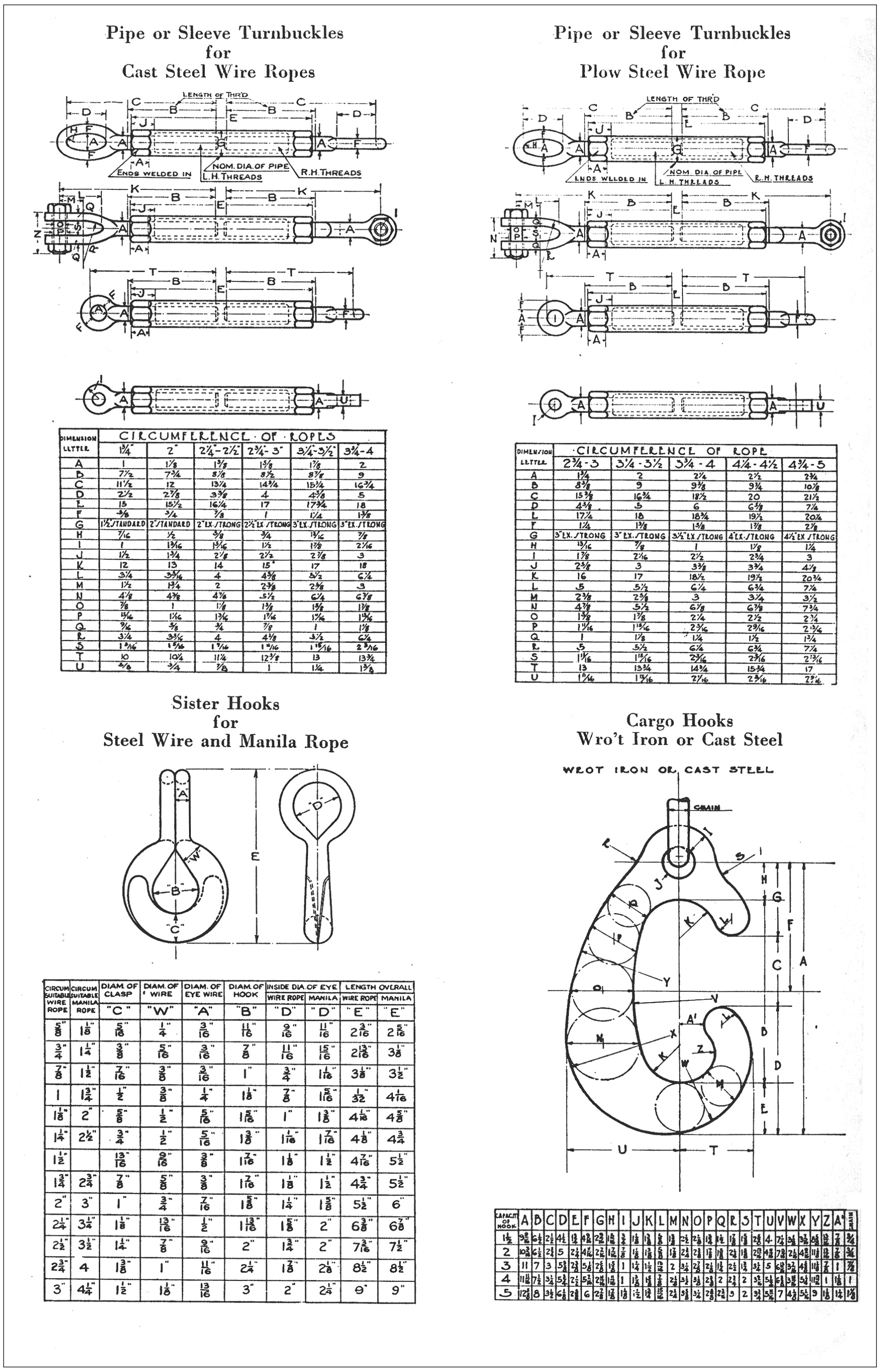
FOR PLOW STEEL ROPE

SIZE OF ROPE	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
2 3/4"-3"	11 1/4"	10"	9"	3 3/8"	1 1/2	1 1/8	1 1/4"	1 5/16	2 1/4	11/16"	1/2"	1 11/16	4 1/2"	3 1/2"	3/8"	1 1/4"
3 1/4"-3 1/2"	13 3/4"	12 1/4"	11"	4 1/8"	1 7/8"	1 3/8"	1 1/2"	1 1/8"	2 3/4"	1 3/16	5/8"	2 1/16	5 1/2"	4 3/16	3/8"	1 1/2"
3 3/4"-4"	16 1/4"	14 5/8	12 7/8	4 7/8"	2 1/8"	1 5/8	1 3/4"	1 7/8"	3 1/4"	1 5/16	3/4"	2 3/16	6 1/2"	5 1/4"	1/2"	1 3/4"
4 1/4"-4 1/2"	18 3/4	16 3/4	14 7/8	5 5/8"	2 1/2"	1 7/8	2"	1 9/16	3 3/4"	1 1/16	7/8"	2 11/16	7 1/2"	6 3/16	1/2"	2"
4 3/4"-5"	18 3/4	16 3/4	14 7/8	5 5/8	2 1/2"	1 7/8	2"	1 9/16	3 3/4"	1 1/16	7/8"	2 11/16	7 1/2	6 3/16	1/2"	2"

Fig. 13-14 **Specifications of Rigging Hardware** – Typical specifications for different types of hardware used in ship rigging of the period.

allowed the proper temperature necessary for optimum natural draft to be maintained within each section of the lower funnel even in instances where one of the two boiler rooms sharing that funnel might be shut down.

Further division was required within the lower Nos 2 and 3 Funnels to provide for the individual operation of certain boilers which were designed to supply steam for the continued operation of the electric plant, fire and sanitary pumps, ventilation fans and other ship's auxiliaries and equipment when the main steam plant was either shut down or disabled. Five separate flues were created within the after section of the lower No.3 Funnel to allow for individual operation of each of the five single-ended boilers in No.1 Boiler Room, while two separate flues were created within the forward section for the two port boilers in No.2 Boiler Room, each of which had a separate connection to the auxiliary steam range running along the working crew passageway on E Deck. Two separate flues were



Pipe or Sleeve Turnbuckles
for
Cast Steel Wire Ropes

DIMENSION LETTER	CIRCUMFERENCE OF ROPES					
	1 3/4"	2"	2 1/4"-2 1/2"	2 3/4"-3"	3 1/4"-3 1/2"	3 3/4-4
A	1	1 1/8	1 3/8	1 5/8	1 7/8	2
B	7 1/2	7 3/4	8 1/8	8 1/2	8 7/8	9
C	11 1/2	12	13 1/4	14 3/4	15 3/4	16 3/4
D	2 1/2	2 7/8	3 3/8	4	4 5/8	5
E	15	15 1/2	16 1/4	17	17 3/4	18
F	5/8	3/4	7/8	1	1 1/4	1 3/8
G	1 1/2" STANDARD	2" STANDARD	2" EX. STRONG	2 1/2" EX. STRONG	3" EX. STRONG	3" EX. STRONG
H	7/16	1/2	5/8	3/4	13/16	7/8
I	1	1 3/16	1 5/16	1 1/2	1 7/8	2 1/16
J	1 1/2	1 3/4	2 1/8	2 1/2	2 7/8	3
K	12	13	14	15"	17	18
L	3 1/4	3 5/16	4	4 3/8	5 1/2	6 1/4
M	1 1/2	1 3/4	2	2 3/8	2 5/8	3
N	4 1/8	4 3/8	4 7/8	5 1/2	6 1/4	6 7/8
O	7/8	1	1 1/8	1 3/8	1 5/8	1 7/8
P	15/16	1 1/16	1 3/16	1 7/16	1 11/16	1 13/16
Q	9/16	5/8	3/4	7/8	1	1 1/8
R	3 1/4	3 5/16	4	4 3/8	5 1/2	6 1/4
S	1 3/16	1 5/16	1 9/16	1 11/16	1 15/16	2 3/16
T	10	10 1/4	11 1/4	12 3/8	13	13 3/4
U	5/8	3/4	7/8	1	1 1/4	1 3/8

Pipe or Sleeve Turnbuckles
for
Plow Steel Wire Rope

DIMENSION LETTER	CIRCUMFERENCE OF ROPE				
	2 3/4-3	3 1/4-3 1/2	3 3/4-4	4 1/4-4 1/2	4 3/4-5
A	1 3/4	2	2 1/4	2 1/2	2 3/4
B	8 3/8	9	9 3/8	9 3/4	10 1/8
C	15 3/8	16 3/4	18 1/2	20	21 1/2
D	4 5/8	5	6	6 5/8	7 1/4
E	17 1/4	18	18 3/4	19 1/2	20 1/4
F	1 1/4	1 3/8	1 5/8	1 7/8	2 1/8
G	3" EX. STRONG	3" EX. STRONG	3 1/2" EX. STRONG	4" EX. STRONG	4 1/2" EX STRONG
H	13/16	7/8	1	1 1/8	1 1/4
I	1 7/8	2 1/16	2 1/2	2 3/4	3
J	2 5/8	3	3 3/8	3 3/4	4 1/8
K	16	17	18 1/2	19 1/2	20 3/4
L	5	5 1/2	6 1/4	6 3/4	7 1/4
M	2 3/8	2 5/8	3	3 1/4	3 1/2
N	4 7/8	5 1/2	6 1/8	6 7/8	7 3/4
O	1 5/8	1 7/8	2 1/4	2 1/2	2 3/4
P	1 11/16	1 15/16	2 3/16	2 9/16	2 13/16
Q	1	1 1/8	1 1/4	1 1/2	1 3/4
R	5	5 1/2	6 1/4	6 3/4	7 1/4
S	1 11/16	1 15/16	2 3/16	2 5/16	2 13/16
T	13	13 3/4	14 3/4	15 3/4	17
U	1 11/16	1 15/16	2 1/16	2 5/16	2 9/16

Sister Hooks
for
Steel Wire and Manila Rope

CIRCUM SUITABLE WIRE ROPE	CIRCUM SUITABLE MANILA ROPE	DIAM. OF CLASP	DIAM. OF WIRE	DIAM. OF EYE WIRE	DIAM. OF HOOK	INSIDE DIA. OF EYE		LENGTH OVERALL	
						WIRE ROPE	MANILA	WIRE ROPE	MANILA
		"C"	"W"	"A"	"B"	"D"	"D"	"E"	"E"
5/8"	1 1/8"	5/16"	1/4"	3/16"	11/16"	9/16"	11/16"	2 3/16"	2 5/16"
3/4"	1 1/4"	3/8"	5/16"	3/16"	7/8"	11/16"	15/16"	2 13/16"	3 1/8"
7/8"	1 1/2"	7/16"	3/8"	3/16"	1"	3/4"	1 1/16"	3 1/8"	3 1/2"
1	1 3/4"	1/2"	3/8"	1/4"	1 1/8"	7/8"	1 5/16"	1/32"	4 1/16
1 1/8"	2"	5/8"	1/2"	5/16"	1 5/16"	1"	1 3/8"	4 1/16"	4 5/8"
1 1/4"	2 1/2"	3/4"	1/2"	5/16"	1 3/8"	1 1/16"	1 7/16"	4 3/8"	4 3/4
1 1/2"		13/16"	9/16"	3/8"	1 7/16"	1 1/8"	1 1/2"	4 7/16"	5 1/2"
1 3/4"	2 3/4"	7/8"	5/8"	3/8"	1 7/16"	1 1/8"	1 1/2"	4 3/4"	5 1/2"
2"	3"	1"	3/4"	7/16"	1 5/8"	1 1/4"	1 5/8"	5 1/2"	6"
2 1/4"	3 1/4"	1 1/8"	13/16"	1/2"	1 13/16"	1 5/8"	2"	6 3/8"	6 7/8"
2 1/2"	3 1/2"	1 1/4"	7/8"	9/16"	2"	1 3/4"	2"	7 3/16"	7 1/2"
2 3/4"	4	1 3/8"	1"	11/16"	2 1/4"	1 7/8"	2 1/8"	8 1/2"	8 1/2"
3"	4 1/4"	1 1/2"	1 1/8"	13/16	3"	2"	2 1/4"	9"	9"

Cargo Hooks
Wro't Iron or Cast Steel

Fig. 13-15 **Specifications of Rigging Hardware**.

also created in the forward section of the lower No.2 Funnel for the two starboard boilers in No.4 Boiler Room, which were outfitted to perform the same secondary role as the two port boilers in No.2 Boiler Room.

The No.4 Funnel acted as a ventilator for the exhaust of air from the galleys on D Deck, the First Class Smoke Room, the B Deck *à la carte* Restaurant, the various pantries, the Turbine Engine Room, the First Class Smoke Room fireplace, the hospitals on D Deck, numerous lavatories and other accommodations. The ventilating fans that fed into the No.4 Funnel were located in the fan room forward of the turbine engine casing on the Boat Deck, and within the funnel itself. At two places in its height the funnel was partially plated across horizontally to prevent rain from falling into the space below. Gutters directed the water to a drain leading to the deck outside.

The four funnels were painted in the standard 'White Star Buff' color with black toppings. The black paint was to hide the residue that came with coal-fired

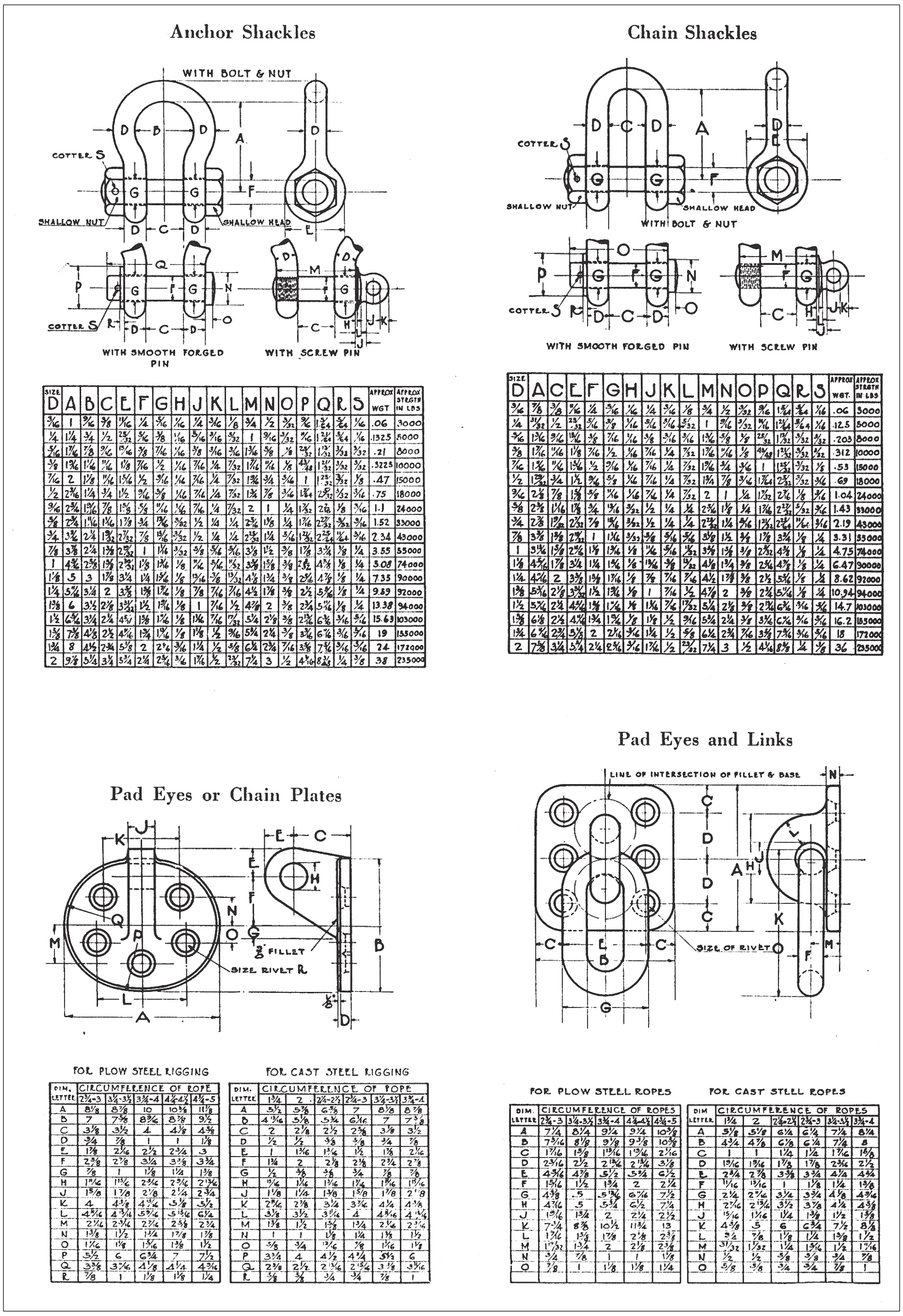

Anchor Shackles
WITH BOLT & NUT
COTTER S
SHALLOW NUT
SHALLOW HEAD
WITH SMOOTH FORGED PIN
WITH SCREW PIN
Chain Shackles
WITH BOLT & NUT
WITH SMOOTH FORGED PIN
WITH SCREW PIN
Pad Eyes or Chain Plates
FILLET
SIZE RIVET R
Pad Eyes and Links
LINE OF INTERSECTION OF FILLET & BASE
SIZE OF RIVET
FOR PLOW STEEL RIGGING
FOR CAST STEEL RIGGING
FOR PLOW STEEL ROPES
FOR CAST STEEL ROPES
CIRCUMFERENCE OF ROPE
CIRCUMFERENCE OF ROPES

Fig. 13-16
Specifications of Rigging Hardware.

furnaces. Each funnel had an elliptical cross-section that measured 24ft 6in x 19ft externally, with an aft rake of 2in per ft, or about 80°. Their average height above the level of the furnace bars (firebars) was 150ft. They were of riveted-plate construction strengthened internally by double-riveted angle-bar frames. The individual plates were lapped at their vertical seams and single-riveted. The horizontal butts were single-riveted and butted flush to one another. Each funnel was fitted with a ladder and platform on the forward side to provide access to the whistles. The ladders followed the rake of the funnels, except for the lower 7ft that angled to meet the casing tops perpendicularly. Also fitted to the exteriors of the funnels were the boiler steam escape pipes both fore and aft. These pipes were made of very light copper, clipped to the funnels, with the tops beaded to provide rigidity. Where the pipes passed through the deck, iron glands lined with lead were used to allow for expansion. The steam escape pipes were not led to the top of the funnel, and

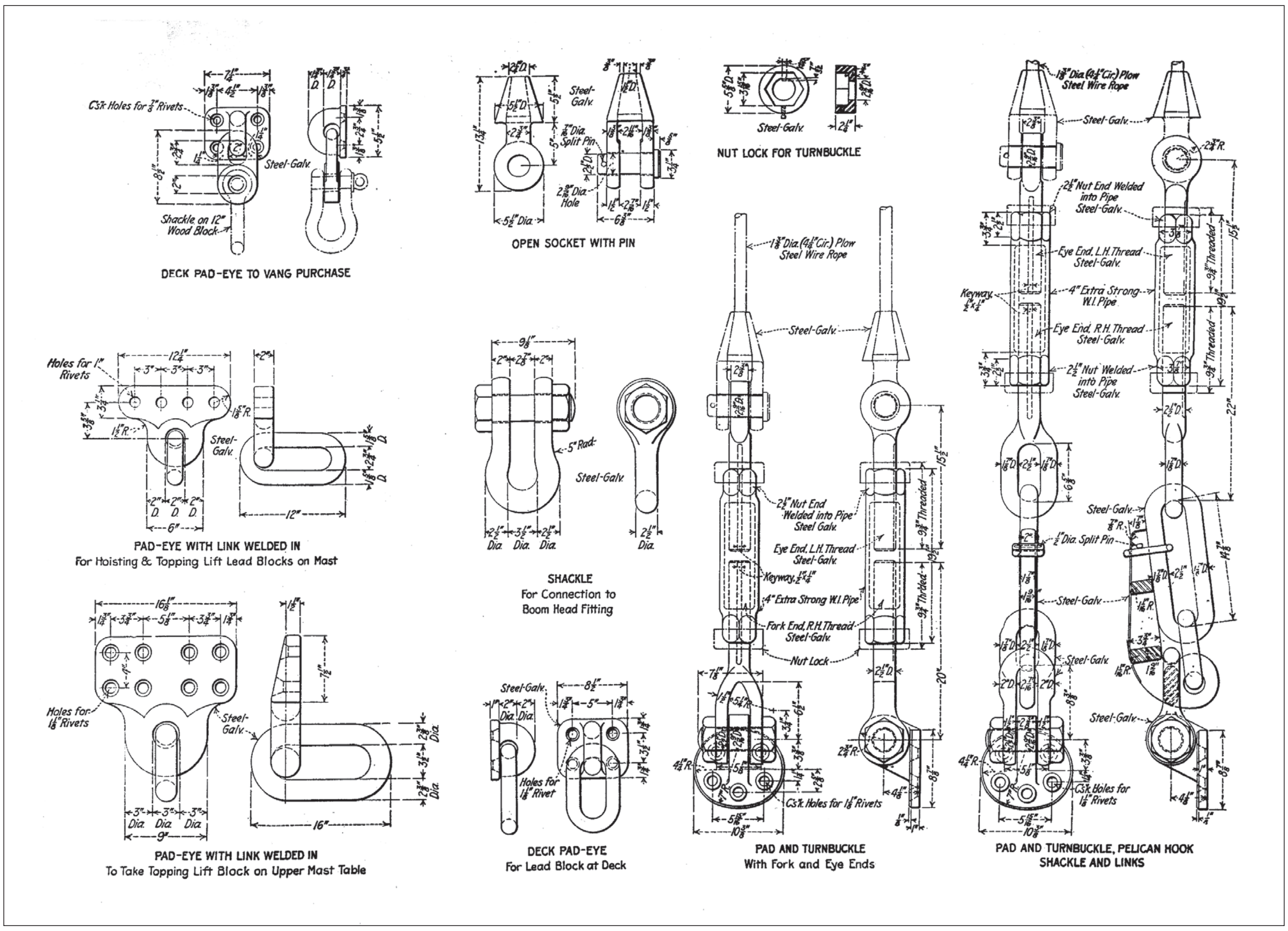

DECK PAD-EYE TO VANG PURCHASE
Shackle on 12" Wood Block
Steel-Galv.
OPEN SOCKET WITH PIN
NUT LOCK FOR TURNBUCKLE
PAD-EYE WITH LINK WELDED IN
For Hoisting & Topping Lift Lead Blocks on Mast
SHACKLE
For Connection to Boom Head Fitting
PAD-EYE WITH LINK WELDED IN
To Take Topping Lift Block on Upper Mast Table
DECK PAD-EYE
For Lead Block at Deck
PAD AND TURNBUCKLE
With Fork and Eye Ends
PAD AND TURNBUCKLE, PELICAN HOOK
SHACKLE AND LINKS
Plow Steel Wire Rope
Nut End Welded into Pipe
Eye End, L.H. Thread
4" Extra Strong W.I. Pipe
Fork End, R.H. Thread
Nut Lock
Keyway
Csk. Holes for 1⅛" Rivets

Fig. 13-17 **Specifications of Rigging Hardware**.

for good reason. It was not uncommon for fine ash to fall down the pipes if they were led too close to the top of the funnel, which tended to plug the drain holes in the safety valves below.

The steam supply pipes for the whistles were mounted separately on the forward side of the funnels, running parallel and forward of the steam escape pipes. These pipes made a sharp bend to port before entering the casings. The whistles on the Nos 3 and 4 Funnels were non operational, although visual continuity was upheld by fitting these funnels with access ladders, platforms and non-functional steam supply pipes.

Specifications for the funnels are as follows:

Principal Funnel Specifications

Funnel	Exterior Funnel Dimensions	Inner Funnel Dimensions	Height above firebars	Height above Boat deck (approximate)
1	24ft 0in x 19ft 0in	19ft 0in x 14ft 6in	149ft 5in	70ft 0in
2	24ft 0in x 19ft 0in	20ft 0in x 15ft 3in	150ft 3½in	74ft 0in
3	24ft 0in x 19ft 0in	17ft 3in x 13ft 3in	150ft 4in	74ft 0in
4	24ft 0in x 19ft 0in	N/A	N/A	73ft 0in

The funnels were each steadied by twelve GSWR shrouds, six on each side port and starboard. The funnel eye plates were located on a stiffening band coinciding with the bottom edge of the black paint, 18ft below the top of the funnels. The shrouds were of 4in-circumference (1¼in-diameter) GSWR. Both ends of the shrouds were fitted with thimbles, the tops of the shrouds being secured to the funnel by shackles. The bottom of the shrouds attached to hemp rope lanyards, which in turn were rove through shackles attached to pad eyes in the decking. Because the funnels would lengthen when heated (the temperature of the smoke passing up the funnel was about 600° F), it was the general practice, before lighting the fires, to slacken off the shrouds a sufficient amount to allow for this extension.

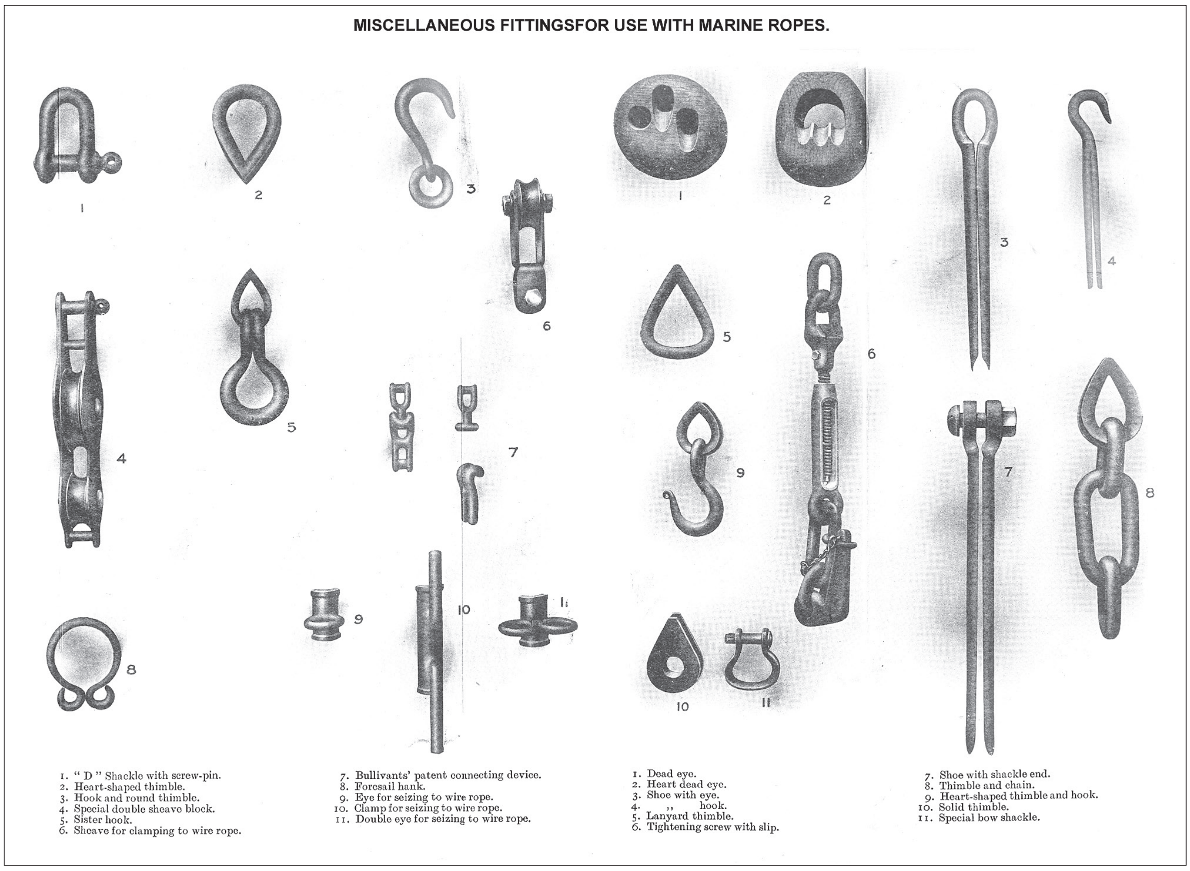

MISCELLANEOUS FITTINGSFOR USE WITH MARINE ROPES.
1. " D " Shackle with screw-pin.
2. Heart-shaped thimble.
3. Hook and round thimble.
4. Special double sheave block.
5. Sister hook.
6. Sheave for clamping to wire rope.
7. Bullivants' patent connecting device.
8. Foresail hank.
9. Eye for seizing to wire rope.
10. Clamp for seizing to wire rope.
11. Double eye for seizing to wire rope.
1. Dead eye.
2. Heart dead eye.
3. Shoe with eye.
4. ,, hook.
5. Lanyard thimble.
6. Tightening screw with slip.
7. Shoe with shackle end.
8. Thimble and chain.
9. Heart-shaped thimble and hook.
10. Solid thimble.
11. Special bow shackle.

Fig. 13-18 **Rigging Hardware**.

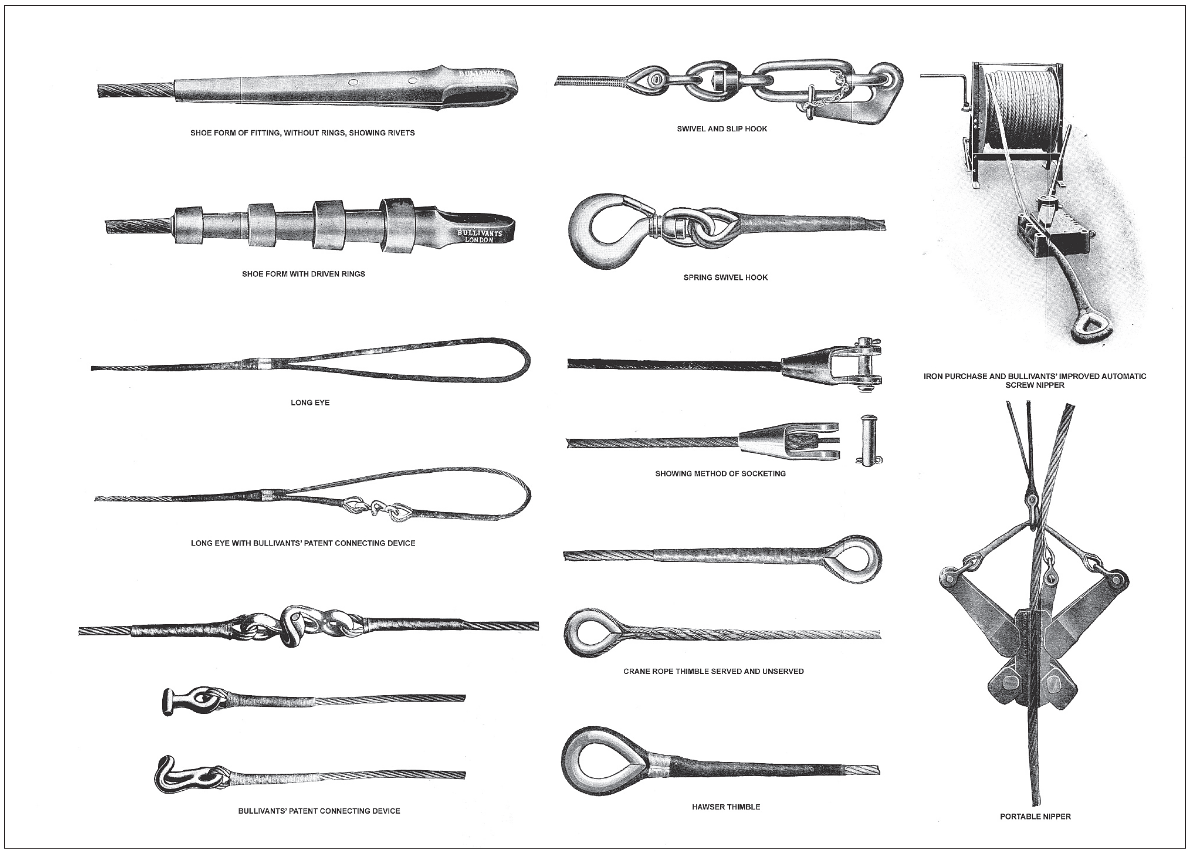

SHOE FORM OF FITTING, WITHOUT RINGS, SHOWING RIVETS
SHOE FORM WITH DRIVEN RINGS
BULLIVANTS LONDON
LONG EYE
LONG EYE WITH BULLIVANTS' PATENT CONNECTING DEVICE
BULLIVANTS' PATENT CONNECTING DEVICE
SWIVEL AND SLIP HOOK
SPRING SWIVEL HOOK
SHOWING METHOD OF SOCKETING
CRANE ROPE THIMBLE SERVED AND UNSERVED
HAWSER THIMBLE
IRON PURCHASE AND BULLIVANTS' IMPROVED AUTOMATIC SCREW NIPPER
PORTABLE NIPPER

Fig. 13-19 **Rigging Hardware**.

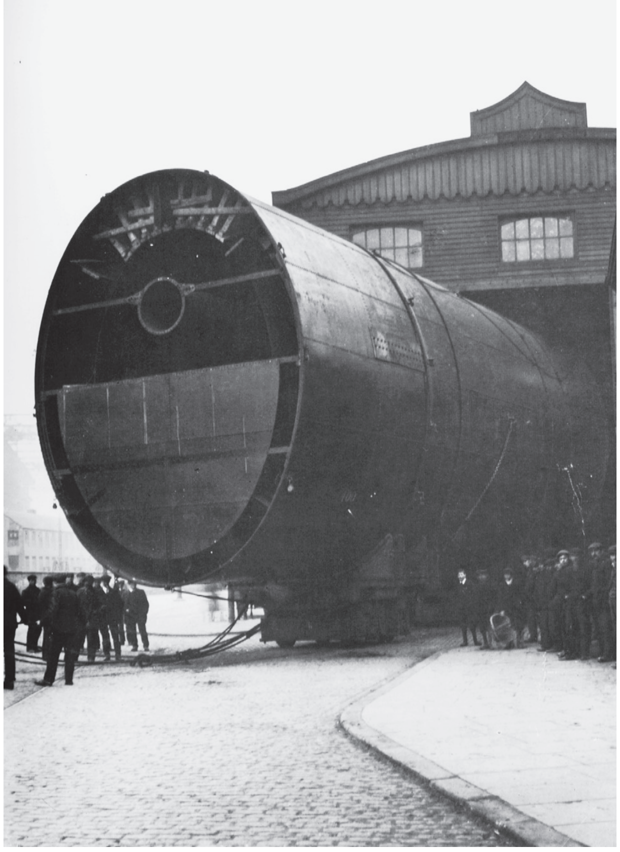


Fig. 13-20 ***Olympic*'s No.4 Funnel Leaves the Shed** – *Olympic*'s No.4 Funnel leaving the shops. The large pipe visible toward the top (forward) portion of the funnel is the galley flue pipe. While this image illustrates the immensity of the funnel, it does not reflect the precise appearance of the top of this funnel on *Titanic*, because her No.4 Funnel also contained the flue for the First Class Smoke Room fireplace. The exit for this second flue, as well as two large rectangular ventilation openings, were included the solid plate seen here covering the lower (after) part of the funnel top. *(*The Shipbuilder*/Authors' collection)*

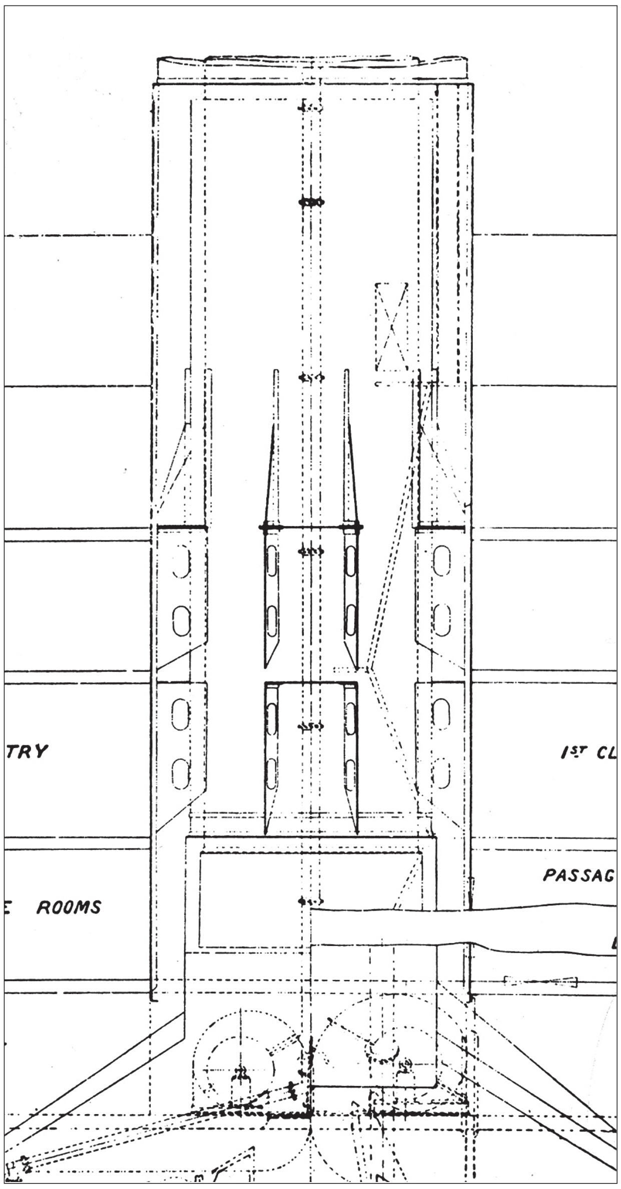
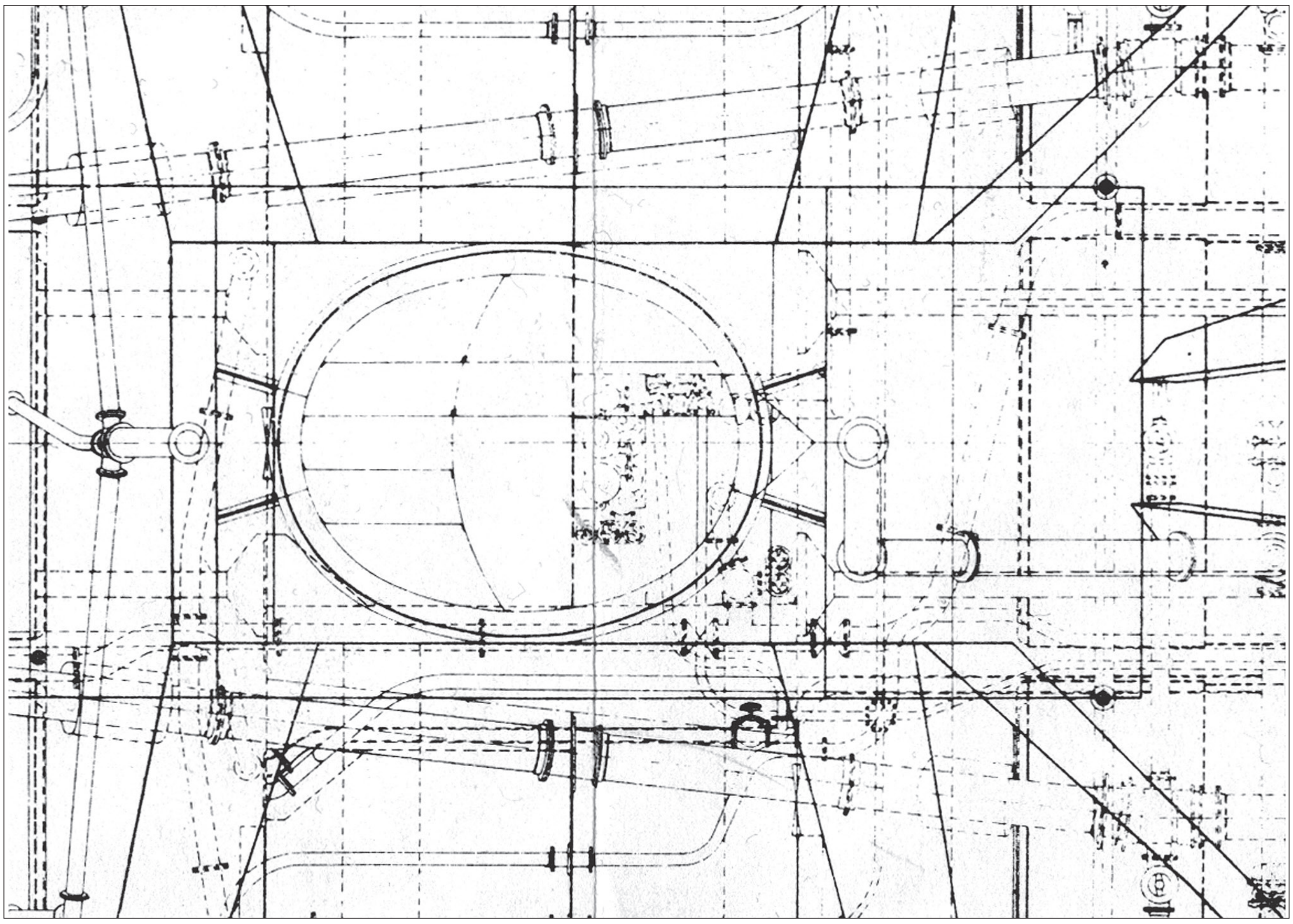


Fig. 13-21 **Transverse Section through Nos 1 & 2 Boiler Casing** – A section showing the lower portion of the No.3 Funnel and the network of support webs that connected it to the sides of the casing. In this view, one set of ladders and gratings within the fidley trunks are also indicated by dotted lines. *(*The Shipbuilder*/Authors' collection)*

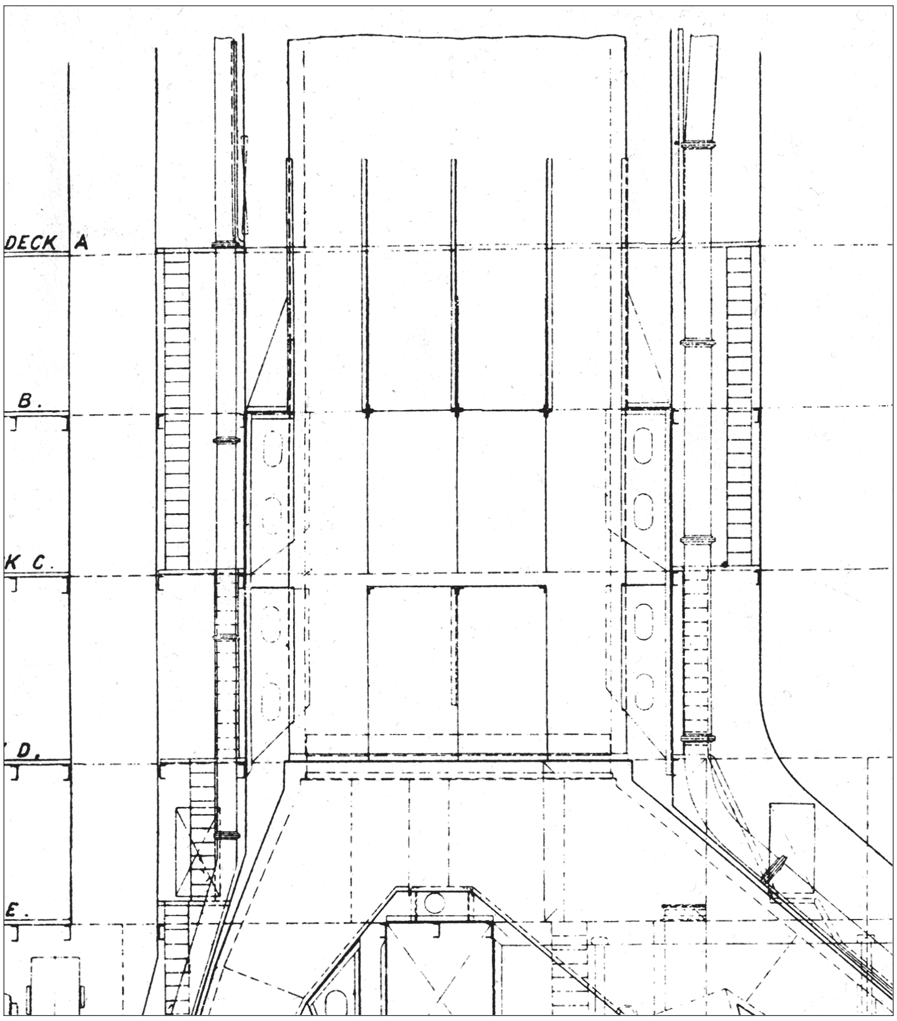
The No.1 Funnel was fitted with special links within the inner two shrouds on each side. These were designed for attaching falls to handle the Engelhardt collapsible lifeboats mounted on the roof of the Officer's Quarters deckhouse. The links were installed at different elevations on their shrouds to compensate for the sheer of the deck and the angle of the shroud to the funnel. The forward links were inserted into the shrouds 30ft from the funnel shackles; the aft link 28ft from the same.

Located on the upper stiffening band of the funnels were eyes with small iron blocks to accommodate gantlines. These lines were used to rig bosun's chairs for use by the painters, as well as for hoisting scaffolding for maintenance purposes. There were four lines, two on each side (port and starboard) that were permanently rigged. During construction work and paint touch-ups, additional lines could be rigged as needed. The gantlines were lashed to the lower ends of the funnel shrouds when not in use. Secondary eyes were also mounted at the midpoints of the funnels to accommodate scaffolding or bosun's chairs for maintenance work.

To prevent the accumulation of moisture on the interior surfaces of the funnels when not in use, covers were fitted above them. They could be positioned to overlap a moderate amount to allow sufficient space for the egress of the smoke from an auxiliary fire or stoves. These covers were made of canvas because of their ease of use in shipping and unshipping. The covers were supported by crossed rods raised over the mouth of the funnel; the canvas was spread over them and laced down to the edge of the funnel tops. The covers were put in place from the interior of the funnel. A platform was



Above Fig. 13-22 **Plan View Through Nos 1 & 2 Boiler Casing** – The base of the lower No.3 Funnel is shown just above the top of the uptakes for Nos 1 and 2 Boiler Rooms. *(*The Shipbuilder*/Authors' collection)*



Left Fig. 13-23 **Longitudinal Section Through Nos 1 & 2 Boiler Casing** – A section showing the lower portion of the No.3 Funnel. In this view, the upper portion of the uptakes for Nos 1 and 2 Boiler Rooms is shown coming together beneath the funnel. Part of the support structure beneath the funnel is visible, transmitting the weight of this structure to the deck beams on the Middle Deck (F) as well as to the bottom structure through WTB J. Ladders and platforms within the fidley trunks are shown, as are the doors leading from the boiler rooms into the working crew passageway on the Upper Deck (E). *(*The Shipbuilder*/Authors' collection)*

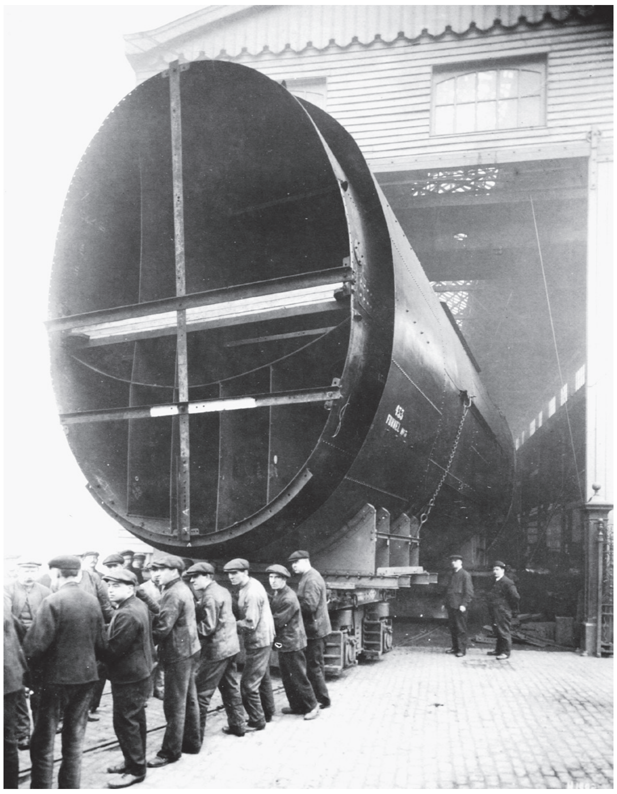


Fig. 13-24 **Lower Section of No.3 Funnel** – The lower section of *Britannic*'s No.3 Funnel leaving the shop at Harland & Wolff. This view, looking into the top end, clearly shows the inner and outer funnel, as well as some of the baffling which divided each lower funnel into separate flues to provide optimum draft to those boilers which were intended to be used individually when the remainder of the steam generation plant was shut down. In this view, the arched transverse division separates the lower funnel into forward and after flues for Nos 2 and 1 Boiler Rooms, respectively. The five smaller flues towards the bottom will individually serve the smaller single-ended boilers in the No.1 Boiler Room, while the two divisions at the upper left created individual flues for the two port boilers in No.2 Boiler Room, which had direct connections to the auxiliary steam range. *(H&W/Authors' collection)*

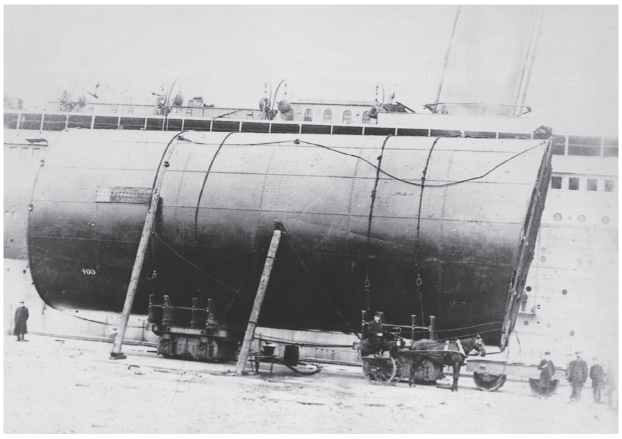


Fig. 13-26 **No.4 Funnel on Tram** – *Olympic*'s No.4 Funnel awaits installation after arriving at the Fitting-Out Wharf on Harland & Wolff's rail system. *(H&W/Authors' collection)*

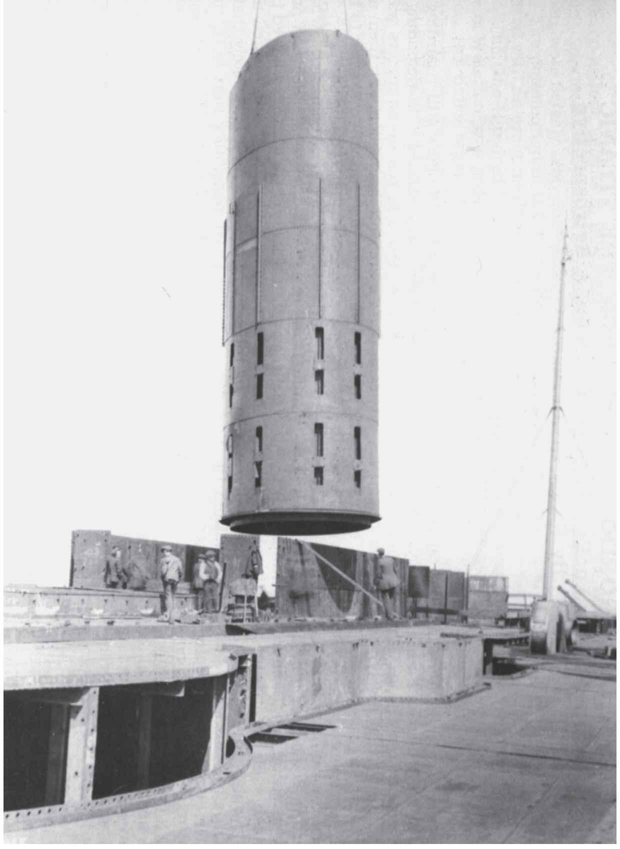


Fig. 13-25 **Lower Section of No.3 Funnel** – The lower section of the No.3 Funnel being lowered into the Nos 1 and 2 Boiler Casing on *Britannic*. *(H&W/Authors' collection)*

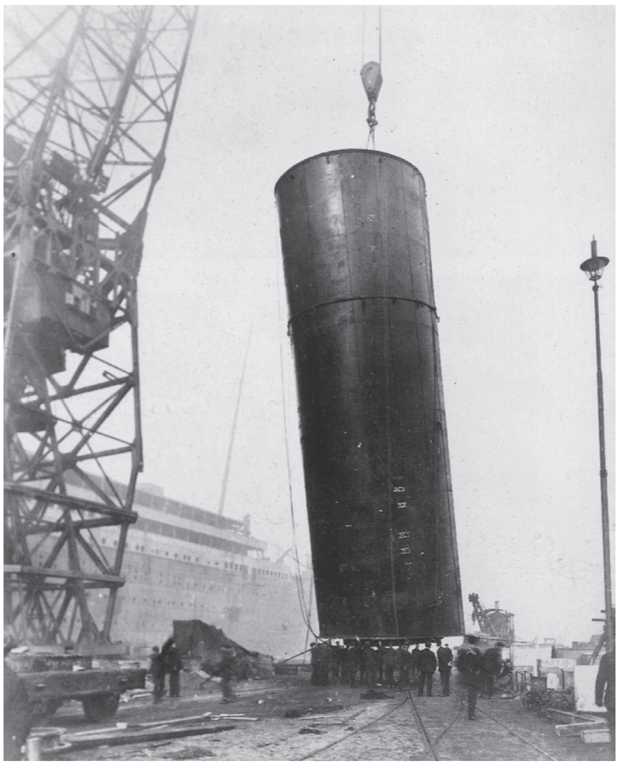


Fig. 13-27 **No.3 Funnel Being Hoisted** – The upper section of *Olympic*'s No.3 Funnel being lifted aboard the ship. *(H&W/Authors' collection)*

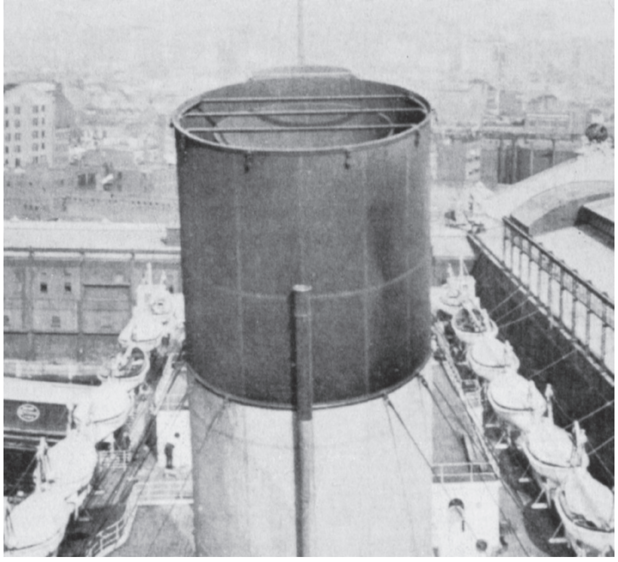
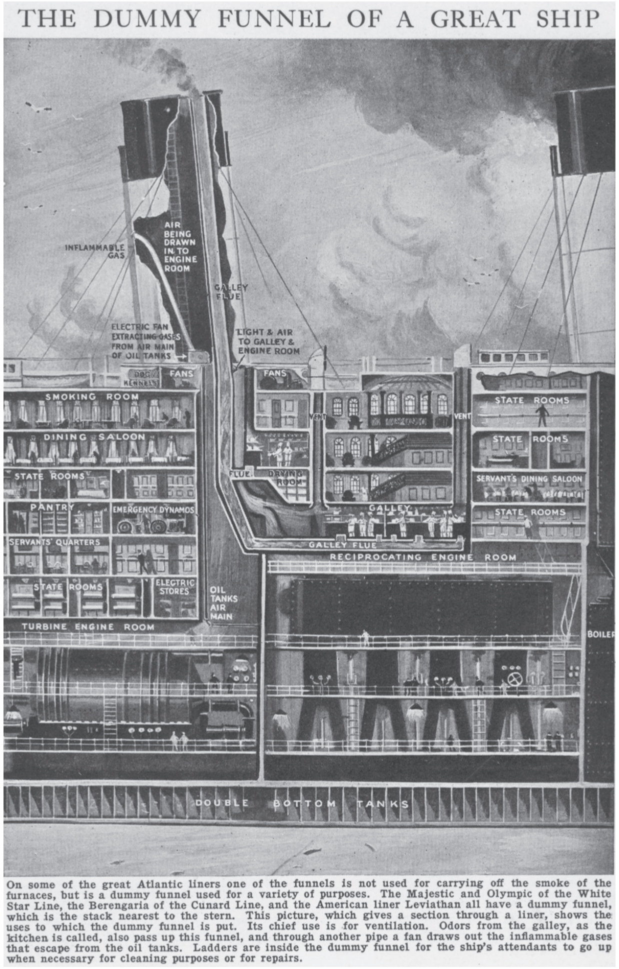


Fig. 13-28 **Top of the No.3 Funnel** – The top of *Olympic*'s No.3 Funnel *c.* 1913. The inner and outer funnels are easily seen here. The three cross-members braced and stiffened the top of the outer funnel, maintaining its elliptical form. They were also used as attachment points for rigging tackle during cleaning and repairs to the funnel. Additionally, they helped to support the canvas rain covers which would be fitted over the top when all boilers beneath the funnel were unlit.



THE DUMMY FUNNEL OF A GREAT SHIP

INFLAMMABLE GAS
AIR BEING DRAWN IN TO ENGINE ROOM
GALLEY FLUE
ELECTRIC FAN EXTRACTING GASES FROM AIR MAIN OF OIL TANKS
LIGHT & AIR TO GALLEY & ENGINE ROOM
DOG KENNELS
FANS
FANS
SMOKING ROOM
VENT
VENT
STATE ROOMS
DINING SALOON
STATE ROOMS
STATE ROOMS
FLUE
DRYING ROOM
SERVANT'S DINING SALOON
PANTRY
EMERGENCY DYNAMOS
GALLEY
STATE ROOMS
SERVANTS' QUARTERS
GALLEY FLUE
RECIPROCATING ENGINE ROOM
STATE ROOMS
ELECTRIC STORES
OIL TANKS AIR MAIN
TURBINE ENGINE ROOM
BOILER
DOUBLE BOTTOM TANKS

On some of the great Atlantic liners one of the funnels is not used for carrying off the smoke of the furnaces, but is a dummy funnel used for a variety of purposes. The Majestic and Olympic of the White Star Line, the Berengaria of the Cunard Line, and the American liner Leviathan all have a dummy funnel, which is the stack nearest to the stern. This picture, which gives a section through a liner, shows the uses to which the dummy funnel is put. Its chief use is for ventilation. Odors from the galley, as the kitchen is called, also pass up this funnel, and through another pipe a fan draws out the inflammable gases that escape from the oil tanks. Ladders are inside the dummy funnel for the ship's attendants to go up when necessary for cleaning purposes or for repairs.

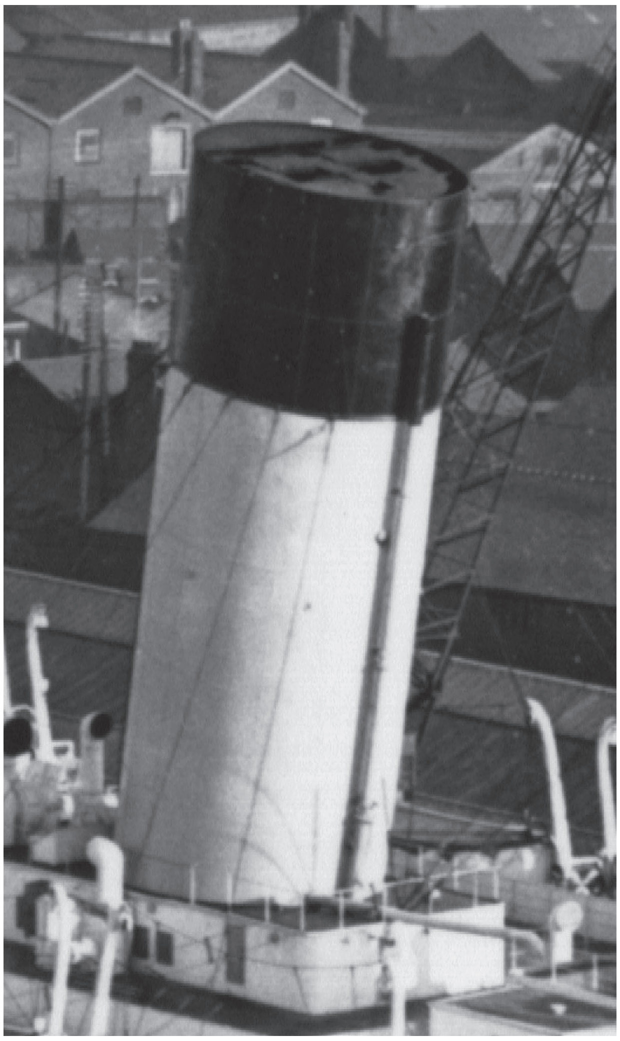


Fig. 13-29 **Top of No.4 Funnel** – *Olympic*'s No.4 Funnel later in her career. By the time this photograph was taken, the First Class Smoke Room fireplace flue had been redirected forward through a horizontal pipe entering base of the funnel. In addition to the fireplace flue, the two rectangular ventilation openings were added, changing the original design to match *Titanic*'s configuration.

Fig. 13-30 **The Dummy Funnel** – An illustration from an early 1920s book called *The Book of Familiar Things*. This image just happens to show *Olympic*'s No.4 Funnel, illustrating its function in an easy-to-understand manner. *(William Daystrom collection)*

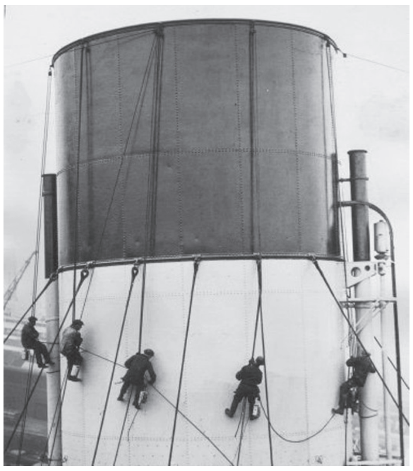


Fig. 13-31 **Painting a Funnel** – Painters suspended from the top of one of *Olympic*'s funnels.

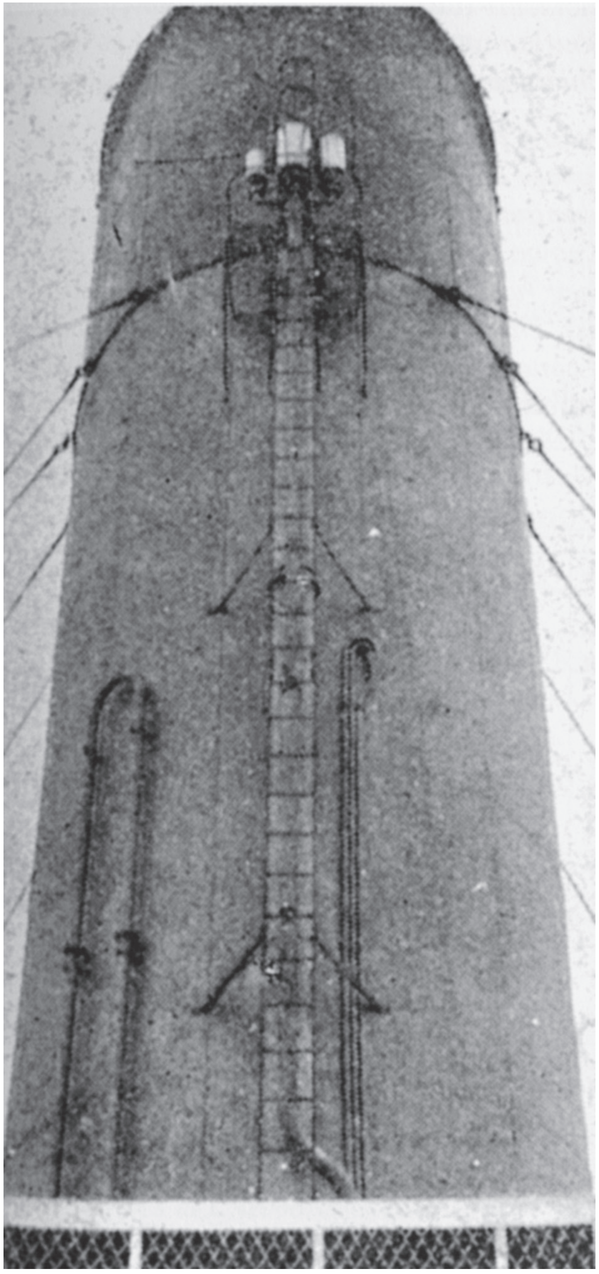


Fig. 13-32 ***Titanic*'s No.1 Funnel** – The steam supply pipe to the whistles is visible just aft of the ladder; at the base of the pipe, the bend to port can be seen. The pipes running up either side of the funnel were part of the water system.

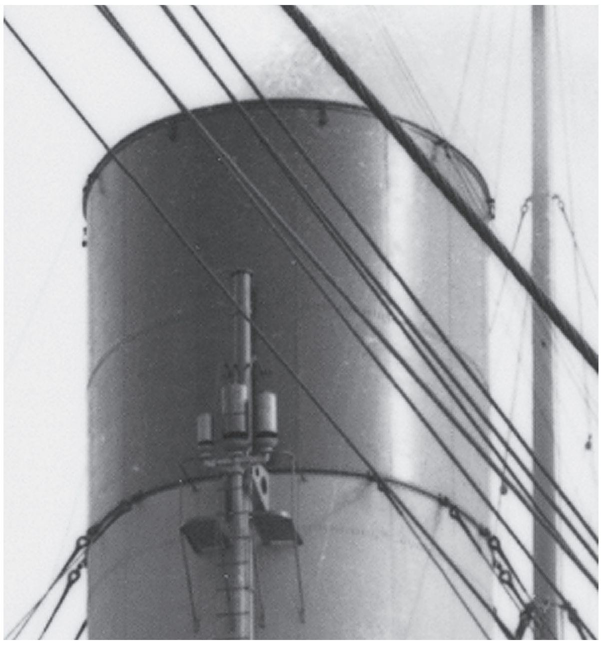


Fig. 13-33 **Funnel Shrouds** – Shackles connected the eyes at the upper ends of the shrouds to eye plates which were riveted to a circumferential band located 18ft below the top of each funnel. From a photograph taken aboard *Olympic*.

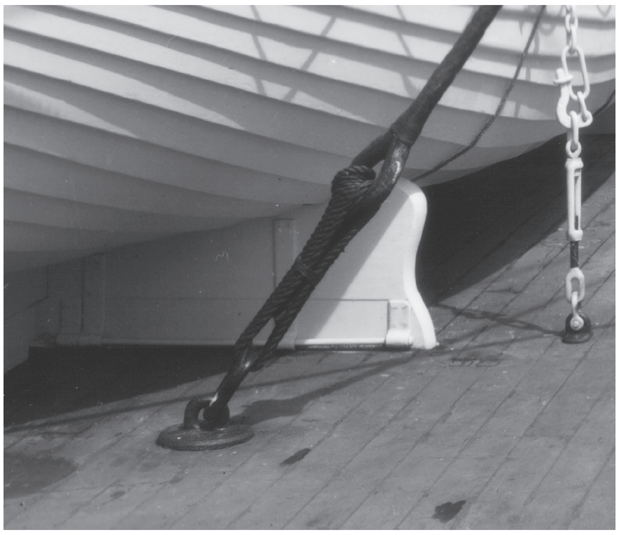


Fig. 13-34 **Funnel Shrouds** – The lower ends of the shrouds were secured to the deck pad eyes with shackles. Unlike the upper end, where the eye of each shroud was shackled directly to the eye plates on the funnel, the eye at the lower end of each shroud was connected to the shackle through an intervening hemp lanyard. This image is from *Olympic*.

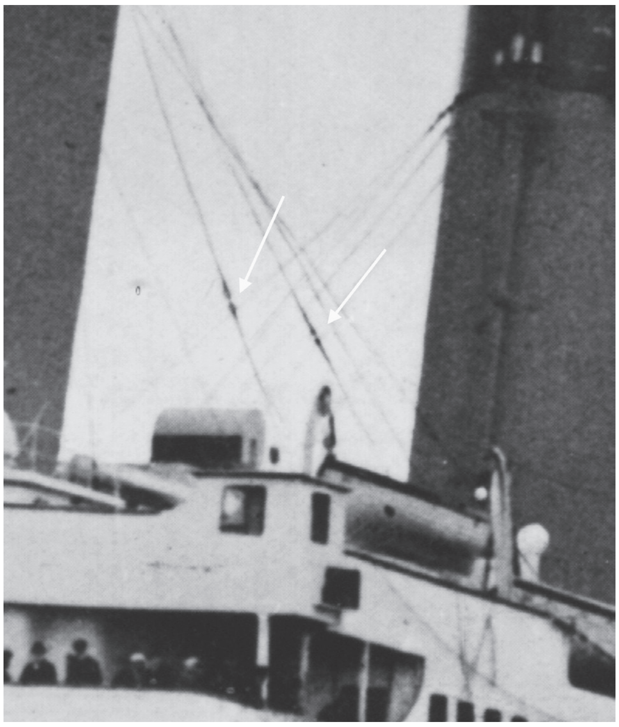


Fig. 13-35 **Shroud Links** – Shroud eye links on *Titanic* designed for attaching the falls to lower the collapsible lifeboats on the Officers' Quarters deckhouse roof. These were never used on the night of the sinking.

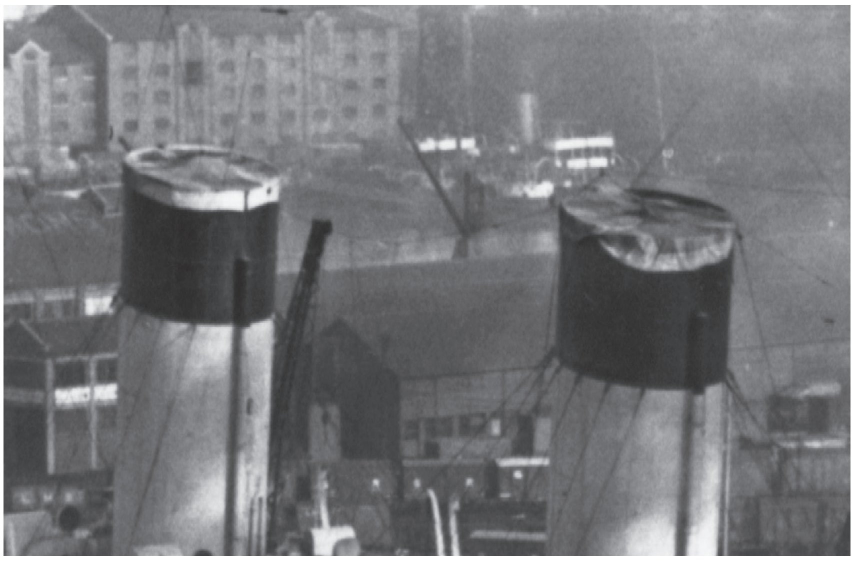


Fig. 13-36 **Funnel Covers** – Canvas rain covers in use on *Olympic* during a time when she remained at dockside for an extended period of time.

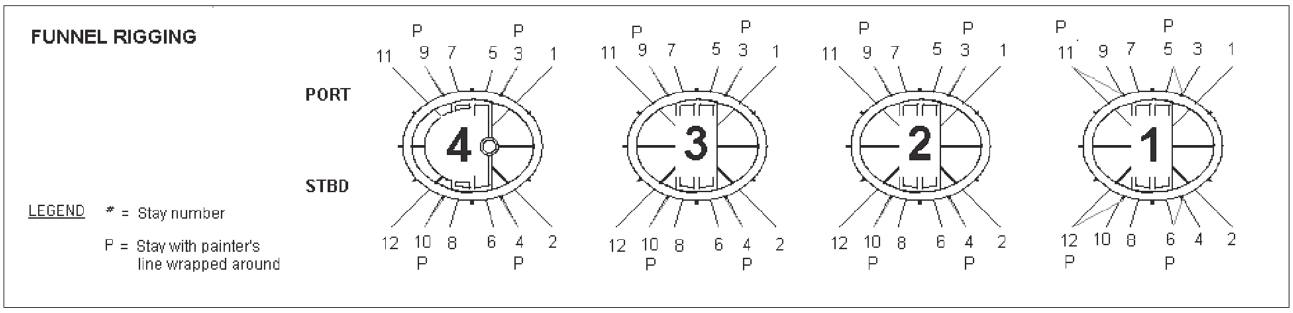


Fig. 13-37 **Painters' Lines** – Diagram of the placement of the gantlines (painters' lines) on *Titanic*. These remained in place on the *Olympic*-class ships and were not stowed; instead, the lower ends were wrapped around the base of the shrouds and secured. *(Illustration by Art Braunschweiger from an original drawing by David Cotgreave)*

fitted for this and other purposes about 4ft from the top; access was obtained by iron ladders permanently fitted inside and leading up from below.[4] Doors were provided in the casings for access to the interior of the funnels and uptakes.

Notes

1. A note on terminology regarding 'line' vs. 'rope': A line is a rope that is being used for a specific purpose (as opposed to a coil in storage, or as shipped from the manufacturer). It should also be noted that with all types of rope, including steel wire rope, the manufacturers designated sizes by the diameter. This designation was used in circulars and in specifications. However, seamen and shipbuilders usually adhered to the habit of designating all lines by circumference, and this convention was followed on rigging plans as well.
2. Photographic evidence shows that *Olympic* had a belaying pin rack at the base of her ratlines at some point in her career, however, early photos of *Olympic* and *Titanic* at sea show the flag halyards coiled and lashed to the ratline shrouds at the B Deck level.
3. When *Britannic* was built, Harland & Wolff did away with the teak top poles and continued the masts up to their full height in steel.
4. It was actually possible to ascend to the top of the No.4 Funnel from the Turbine Engine Room. A stoker did this at Queenstown, causing some consternation among the passengers when he was seen looking down from the funnel top.

Chapter 14

Corrosion, Paint and Waterproofing

Paint on a ship had more than an aesthetic value. It also acted as an anti-corrosive coating when applied over steel or iron, and served as a weatherproofing for canvas. Different parts of the hull were subject to different variables of corrosion, and the paint applied was matched accordingly. Painters were included in the crew, and were utilized quite regularly. On G Deck was located a paint store where the painters mixed and tinted their paints. Touch-ups were conducted while in port, and at the end of each season when vessels like *Titanic* were brought in to the shipyard, they were given a complete repainting along with any general repairs or refitting required. Because paint was oil based, it was heavy and, over time, resulted in a buildup of thick layers as coat after coat was applied. After a few years, it was not uncommon to see fittings and machinery around the ship that were covered thickly with paint. Though much of the surface buildup could be chipped off, late pictures of *Olympic* show pipes and other weather deck areas that had been repainted so many times that the paint looks like a rubber coating.

Along with paint, other products such as varnishes and cement were used for protection against corrosion or to act as a sealer. Bitumen-based products covered many bulkheads and decks, while Portland cement, a product still available today, was widely used aboard ship. Cement sealed seams, covered bolt heads, acted as footings for ventilators and machinery, lined the interiors of water tanks and more.

Anticorrosive coverings

The rusting, or corrosion, of iron and steel is a familiar chemical phenomenon. If immersed in pure distilled water, clean iron will not rust, nor will it rust in pure air, however humid. To start the process carbonic acid[1] must be present, but once begun no more is required. As ordinary water and humid air both contain carbonic acid, exposure to either is sufficient to cause rusting; but if well-coated with paint there is no exposure, of course, and consequently, no rusting. Rusting is the slow combination of the iron with the oxygen of the air; both of these are simple elements, and the resulting compound, rust, is an oxide of iron.

Like all chemical reactions, oxidation is greatly accelerated by heat. In steamships, for instance, the structure of the hull adjacent to the boilers corroded much faster than other parts, and deck plating, which was exposed to the heat of the sun's rays, also corroded quickly. In the manufacture of steel plates, water was thrown upon them during the rolling process, and, consequently, all new plates were covered more or less with mill scale, a circumstance that, as realized later, had a significant effect on their rusting tendencies.

Corrosion is also caused by steel fastened to or in close proximity to other metals when exposed to sea water. Sea water, owing to its dissolved salts, has the effect of a weak acid, i.e. it promotes a galvanic current between dissimilar metals; and this circumstance had an important bearing on the rate and nature of the corrosion of ships' hulls. Other metals besides copper are electronegative to iron and cause it to corrode. Lead, tin, and brass alloys have even a greater effect; ordinary rust, and especially mill scale, are also electronegative to iron. In particular, local corrosion of the propeller shaft through galvanic action had always given a great deal of trouble.

It was often observed that brass or copper alloys had a markedly corrosive effect on iron when in contact with sea water. For instance, with underwater sea cocks, which were sometimes made of brass, it was common to find that the surrounding shell plating was deeply corroded. And when the propeller was of bronze like *Titanic*'s, the stern frame and rudder were liable to very pronounced corrosion.

This form of corrosion was guarded against by bolting slabs of zinc (zinc protectors, now called sacrificial anodes) to the contiguous parts of the hull. These, being electropositive to iron, wasted away rapidly, with the benefit that the iron enjoyed almost perfect immunity from corrosion. With cast-steel stern frames it was found that strips of soft iron had a protective effect similar to zinc, with the advantage of cheapness and greater durability.

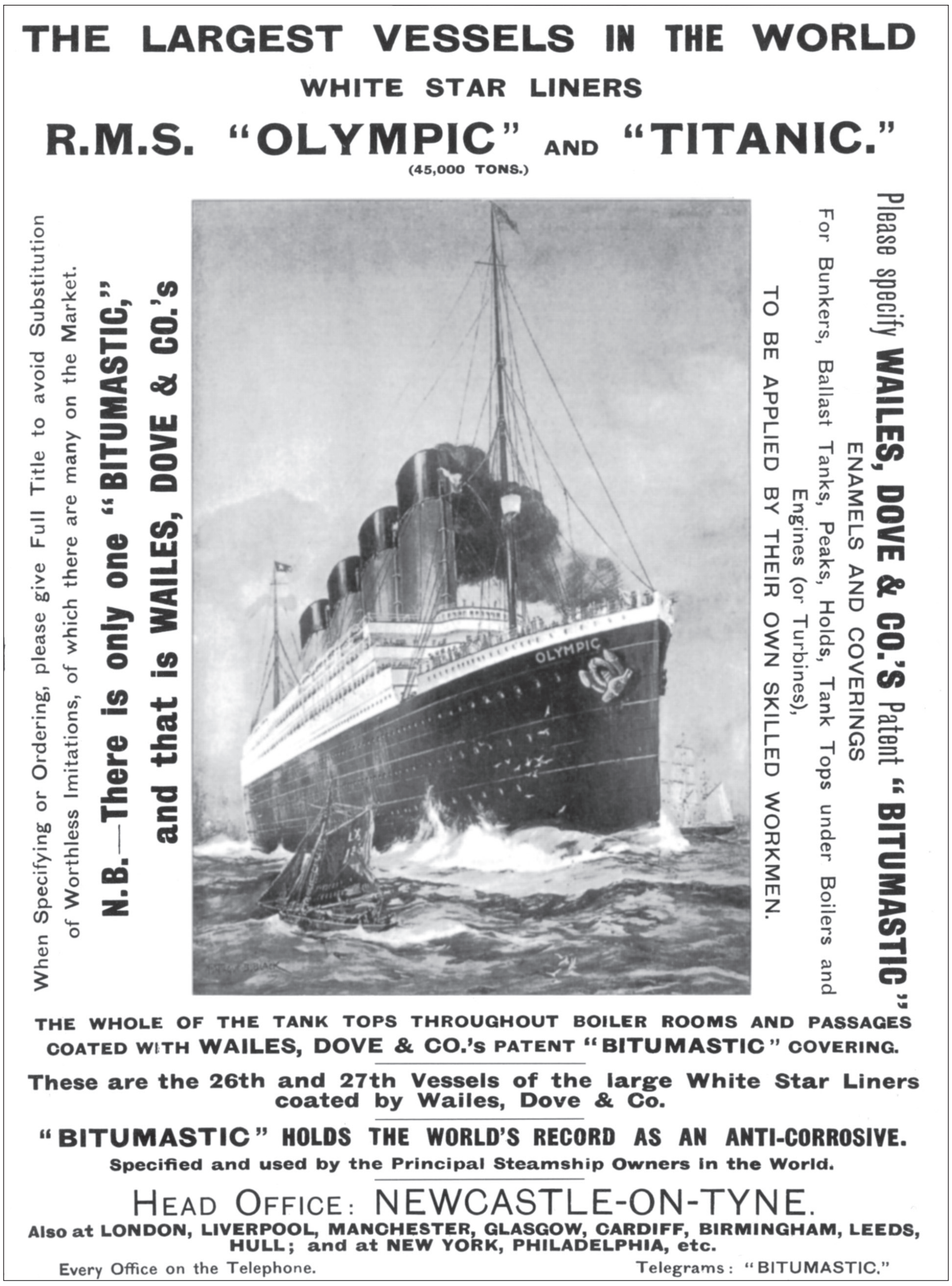


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Fig. 14-1 **Wails, Dover and Co. Advertisement.**

Clean metallic lead had a markedly corrosive effect on iron, but in practice this was not a source of trouble because the lead was rendered inactive by the fact of its becoming covered with a coating of its own oxide. The bilge suction pipes, for instance, were often of lead, and although immersed in bilge water and in contact with the steelwork of the hull, the latter was rarely found to suffer.

The mill scale or magnetic oxide which was found on practically all new steel plates was particularly active in promoting rapid corrosion of the steel by galvanic action every bit as much as copper. Mill scale was peculiar in that, unlike other oxides, it was impervious to water, so that if it entirely covered a plate it would protect it from corrosion. In practice, however, it never did form a perfectly continuous covering, for as it was brittle it broke off locally from riveting and hammering.

If the shell plating of a new vessel was painted before removing the mill scale, it would receive little protection from the paint, for as patches of scale with paint attached became loose and fell off, the resultant bare spots were exposed to widespread galvanic action and the resulting rapid corrosion accelerated the loosening of the remaining scale. Some shipbuilders guarded against the corrosive influence of mill scale by removing it, as much as practicable, before finally painting the steel plates.

Mill scale was not found as much on iron plates, nor did it adhere with such persistency as on those of steel. Because the steel plates used on *Titanic* were manufactured in Harland & Wolff's own Platers' Sheds, it could be seen that the stacks of plates waiting to be raised in the yard were covered with scale. The method sometimes adopted in high-class vessels, and always in warships, was to immerse each plate in a bath of dilute hydrochloric acid (one part of acid diluted in ten to twenty parts of water). After soaking the plates for half an hour or longer, they were washed with alkaline water and scrubbed with machine-driven revolving wire brushes. However, the mill scale could also be removed by allowing it to break off from the effects of the riveting and hammering. Whatever scale was still intact after the riveting was chipped off by hand. This was the method used by Harland & Wolff. *Titanic*'s

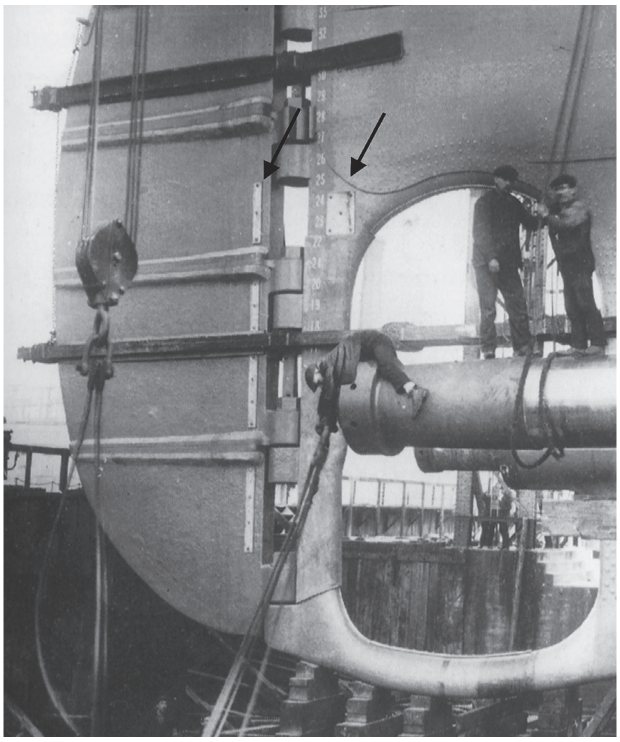

Fig. 14-2 **Sacrificial Anodes** – *Titanic*'s stern frame in her construction berth. The plates indicated by the arrows, today called 'sacrificial anodes', were probably made of zinc rather than soft iron. These plates were easily replaceable when they wore out. It is said that application of such sacrificial anodes to reduce or prevent corrosion of the stern frame and rudder was one of Edward Harland's innovations.

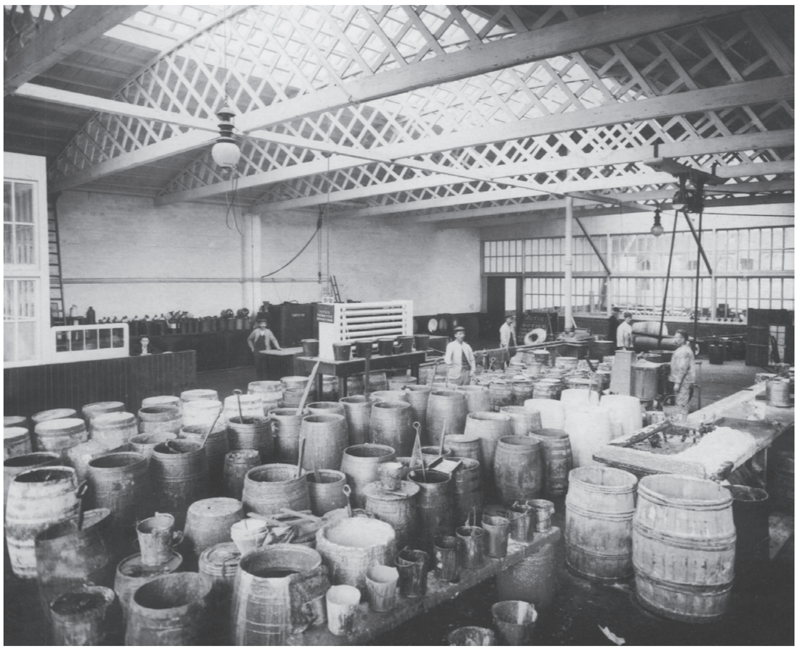

Fig. 14-3 **Harland & Wolff Paint Shop** – The Paint Shop at Harland & Wolf the late 1890s. Tug warning signs can be seen against the back wall of the room. *(H&W/Authors' collection)*

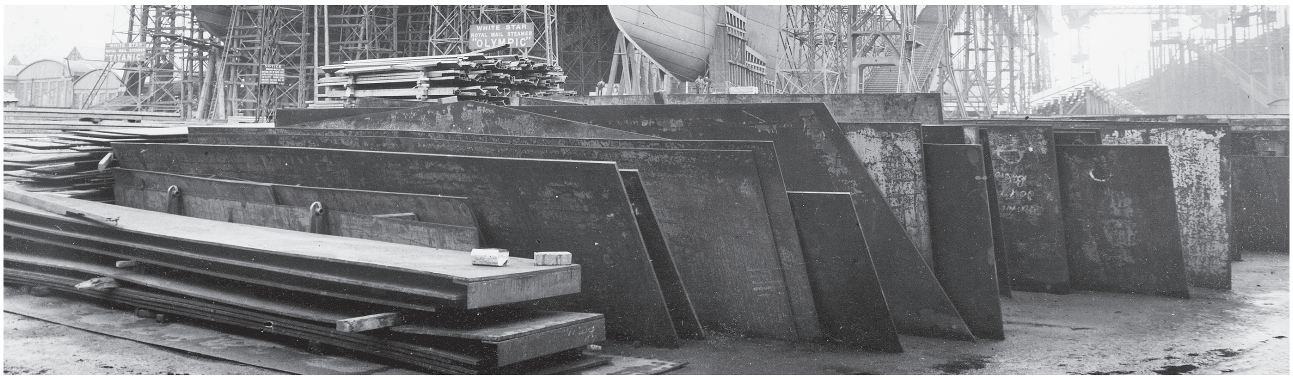

Fig. 14-4 **Mill Scale** – Steel plates await fitting on *Titanic*. The mill scale is clearly visible on the plates. *(Steve Hall collection)*

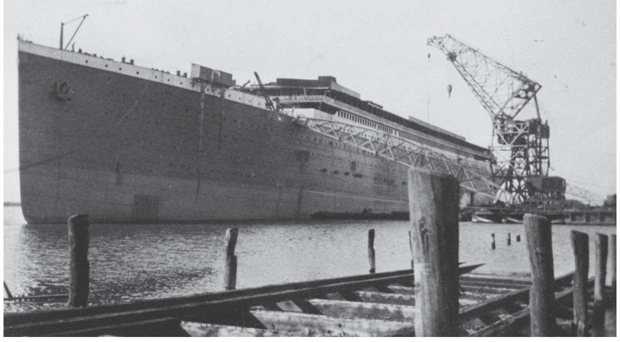

Fig. 14-5 ***Titanic* with Primer** – *Titanic* in the Fitting-Out Wharf. She is seen here in her lead-colored primer, applied shortly after launch. *(Ray Lepien collection)*

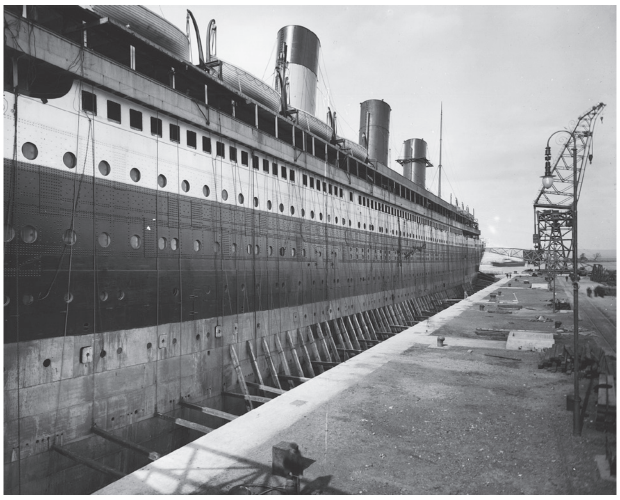

Fig. 14-6 ***Olympic* in the Graving Dock** – *Olympic* in the Thompson Graving Dock, April 1, 1911. The line of demarcation between the primer and the freshly painted black is clearly visible here. A good portion of the paint work above the waterline was completed while the ship was in the Fitting-Out Wharf, but the lower half was painted while the ship was out of the water in drydock for obvious reasons. *(*The Shipbuilder*/ Authors' collection)*

steel was further protected from corrosion by primer that was applied over her plating after it was fitted into place and cleaned.

The primer was made with a pigment of lead chromate or lead sulphate mixed with a vehicle (carrier). Pigment of this type had a slate-gray color, and was commonly used on Harland & Wolff ships. It provided protection against galvanic action and acids, and it dried rapidly. The paint was mixed fresh in the Harland & Wolff Paint Shop for the job at hand.

It should be noted that the primer thought to be the best was made of red lead mixed with pure linseed oil. This mixture created a red-orange-colored paint. Though this color of primer could be seen in use at some shipyards, Harland & Wolff appeared to prefer the gray primer. *Titanic*'s hull at launch, however, would be painted with anti-fouling paint and a black hull, only to have the upper hull repainted in lead-color primer shortly afterwards.[2]

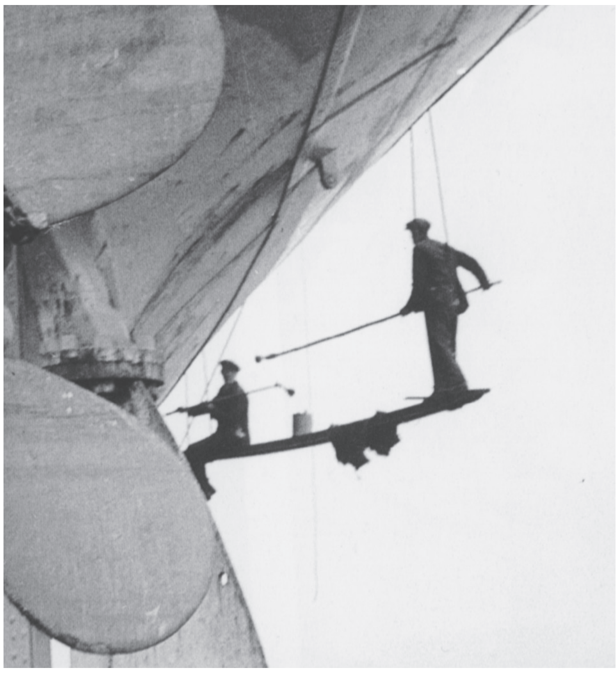

Fig. 14-7 **Painters Under Counter** – Painters at work beneath the counter of a large ship.

Following normal practice, *Titanic* would have been dry-docked at least once a year to apply a coat of anti-fouling paint on the bottom portion of her hull. The object, of course, was to maintain a clean bottom, but at the same time it secured for the underwater shell plating almost complete immunity from external corrosion.

The worst corrosion on steam ships occurred in the vicinity of the coaling hatchways, for as the coal was shot in from above it quickly rubbed off the protective covering, and rainwater sometimes gained access through the hatchways. Throughout the whole bunker, moreover, the coal, by gradually sinking as it was worked out from below, had an abrasive or grinding effect on all exposed parts, laying bare fresh metallic surfaces to corrosive influences. The parts that suffered the most were the exposed flanges of the reverse frames and bulkhead stiffeners, for they presented two surfaces to the coal, and in the case of the reverse frames, the inner surface escaped the periodical cleaning and coating. The isolated cross beams and tie bars also suffered severely from the descending mass of coal. The best preservative coating for coal bunkers was a bituminous paint or black varnish; this dried with a hard yet tough, glossy surface, and if properly applied to clean steel and renewed at sufficiently short intervals corrosion was minimal.

The tendency of the shell plating to corrode under the sidelights was also a factor in anti-corrosion safeguards. When woodwork was bolted to exposed plating, continuous corrosion was caused by sea water getting

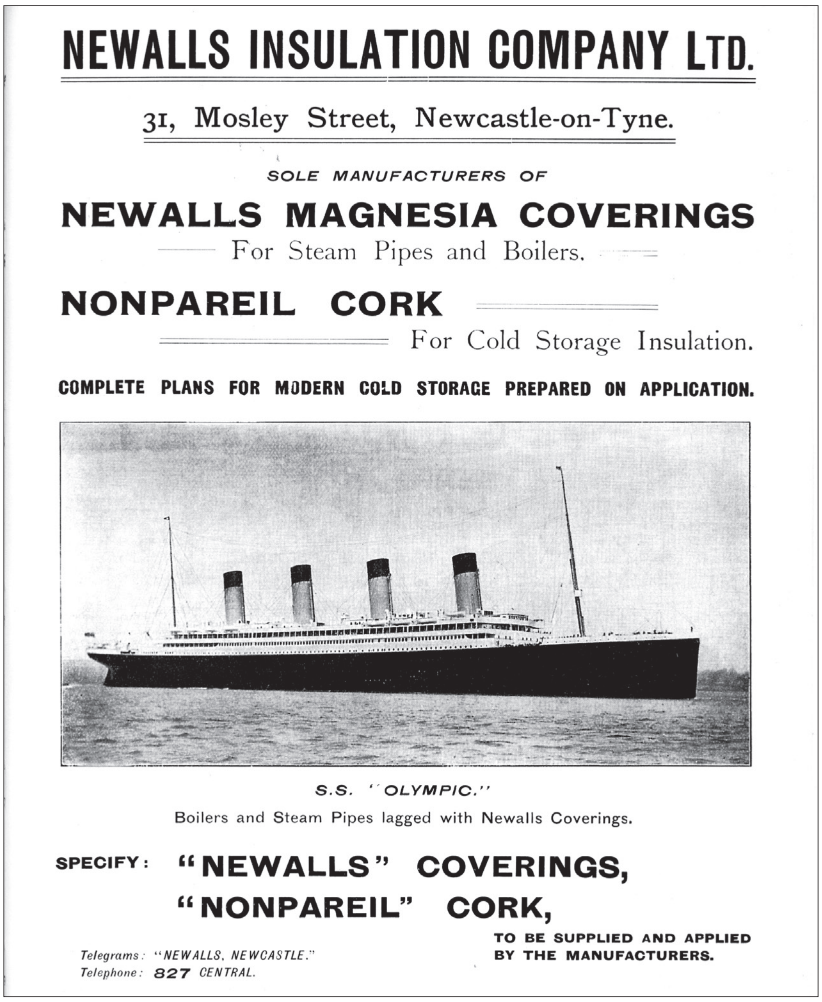

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Fig. 14-8 **Newalls Insulation Co. Advertisement.** *(*The Shipbuilder*/Authors' collection)*

underneath, and saturating and eventually rotting the wood. To prevent this, the weather deck mast wedges were covered with painted canvas. If the wedges leaked, corrosion would occur. Because of this, the classification societies required that the masts should be doubled at this part, and be periodically examined. When there was wood decking laid next to the coaming of the boiler casings, the deck plate or tie to which it connected was especially liable to corrode.

The heat from the boilers was very active in promoting rapid corrosion of the framework of the hull below. All of the structures below the boilers required protection and subsequently were given a coating of bituminous cement. Leakage of hot water from the boilers and the hot and damp conditions of the area were occasionally a source of serious local corrosion. To provide a margin of strength against rapid corrosion, the inner bottom plating framework under the boilers was often made of extra thickness. The desired result was also secured, in great measure, by placing the boilers well up above the floors and Tank Top, and leaving the intervening space as open as possible to allow the free circulation of air. The upper surface of the Tank Top was protected from corrosion by a watertight coating of bituminous cement. Bituminous cement – of a type which did not soften too much when warm – formed an excellent covering.

Titanic's boilers and steam pipes were lagged with 'Newall's Magnesia Coverings', manufactured by Newalls Insulation Co. Ltd, Newcastle. In conjunction with the bottom lagging on the boilers, baffle plates were constructed between the boilers and the Tank Top so as to intercept radiant heat.

A number of excellent bituminous coatings were sold under the trademark 'Bitumastic'. They included Bitumastic solution, a brilliant black paint applied cold to any steel work; Bitumastic enamel, a hard-drying, thick coating applied hot and suitable for bunkers, tanks, bilges and peaks; and Bitumastic cement, applied hot as a substitute for Portland cement. Bitumastic products utilized on *Titanic* were supplied by Wailes, Dove & Co., Newcastle, and were used on the whole of her Tank Top and throughout boiler rooms and passages.[3]

Exterior and interior paints

Oil paint differs from varnish in that it dries by oxidation and increases in bulk, whereas a varnish dries by evaporation and diminishes in bulk. Paint consists of two parts, the vehicle and the pigment. Linseed oil was the usual vehicle in those days; in drying it oxidized and formed a tough, leathery skin termed 'lenoxin'. If used alone it was too thin and porous; to give it the necessary body or substance, a pigment was added – usually a mineral oxide. Although it then formed a tough elastic covering, it was neither perfectly air- nor watertight, for it contained minute pores which enlarged as the paint aged. To provide the durable and watertight surface required, two or more coats were applied so that each could fill or cover the pores or fissures in the one below.

To achieve the desired color in a given paint, there were several pigments in general use in shipyards of the time and into the years which followed: red lead or oxide of lead, white lead or carbonate of lead, red oxide or oxide of iron, oxide of zinc, metallic zinc in a finely divided powder, and lampblack. Although all of these gave good results, the metallic zinc had the advantage that a paint made with it was, under all conditions, perfectly harmless to the steel. So long as a paint remained sound and impervious to water, the pigment, being wrapped up in it, could have no effect on the steel. When it decomposed, however, it became dry and chalky; and the pigment, being thrown into direct metallic contact with the steel, would, if electro-negative, exercise a corrosive effect. Whereas lead and oxide of iron are electro-negative to iron, zinc is electro-positive, so that if a zinc paint decomposed, the resulting contact between the pigment and the steel actually retarded corrosion. In practice, good red lead was rarely found to have any prejudicial effect on steel and it had a more extensive use than any other paint, for it had excellent adhesive and covering qualities and its endurance was often remarkable. It was almost universally used for ships' bottoms for the first and second coats, and alone for inside work.

In applying oil paint, it was essential that the steel was perfectly dry, for if not, its adhesion was very poor. Paint which had been applied to wet plates sometimes tore off in ribbons. If the steel was warm when painted, the adhesive and enduring qualities of the paint were greatly enhanced. As evidence of this, cases were sometimes cited of finding, when breaking up old iron structures, the manufacturer's numbers that had been painted on the hot plates with white lead at the ironworks.

When a vessel's topsides and other exterior work were painted white or gray, the standard was a white lead-and-linseed oil paint, tinted as required. An addition of a carbon black pigment to white would bring about any shade of gray required. The funnel paint had to withstand heat and was mixed with litharge.[4]

It should be noted that even though shipbuilders used lead-based paint, it was already understood by the time of *Titanic* that lead was poisonous. With this known, special care was taken to use non-poisonous paint in passenger areas and for other specified compartments and treatments within the ship.

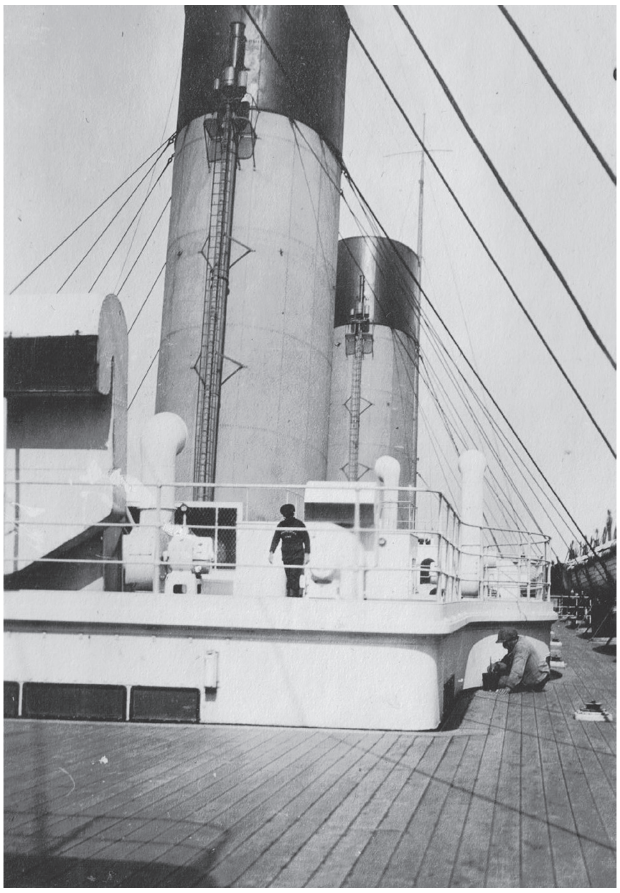


Fig. 14-9 **Painter at Waterway** – A painter touches up the waterway along the raised roof over the Reading & Writing Room on *Olympic*'s Boat Deck in the 1920s. *(Peter Davies-Garner collection)*

The paint colors used aboard ship had much to do with the versatility and the properties of the tints. Some standard ship colors were 'tried-and-true' for many years, became universally adopted among many shipping companies and would have generally applied to *Titanic* as well. For some paints, the color names were not specifically chosen as such, but simply resulted from the chemicals that gave them their protective properties – 'green chromate' for the electric winches, for example.

Following are excerpts taken from a period paint book for ships from the late 1800s. Though some of these specifications were outdated by *Titanic*'s time, they are interesting nonetheless:

> *For rope rigging a good 'blacking' is used consisting of ½ barrel tar, 6 gals spirit, 4lb litharge, 4lb lamp-black, and 2 buckets of boiling brine.*
>
> *Pure red lead, oxide of iron, and white lead mixed with enough black to make it lead-color, all mixed with boiled*

> *oil and driers, but no turps, are the best mixtures for sea use.*
>
> *Red lead mixed with buttermilk or sour beer is a good mixture for a funnel, to be laid on quite thick.*[5]
>
> *Red lead with just enough white to lighten it, and mixed with boiled oil is a good color for masts and yards.*
>
> *Oxide of iron (dark red) mixed with boiled oil and the scrapings of varnish pots is a good mixture for stoke-hole ventilators, and would stand washing off (without soda) a great number of times.*[6]
>
> *A mixture of white lead and tallow, such as engineers use, is the best thing to put on any bright iron work, such as screws of after steering gear etc.*
>
> *Black lead and oil is a good mixture for winch chains.*

The exact tones and shades of *Titanic*'s paint colors may never be determined with absolute certainty as no paint chips or Harland & Wolff paint formulas are known by the author to have survived. If these items do exist, they have not been made available nor has their existence been made public. Other than black-and-white photographs, the *Titanic* historian has to rely on existing White Star Line promotional models, painted color postcards and general specification books. There are color photos of White Star ships publicly available, but only from the period following the White Star–Cunard merger in 1935. Color film would not be used on a grand scale until after the Second World War, and even so, it must be noted that early color photographic images are notoriously unreliable due to chemical degradations that can result in color shifts of certain hues.

Titanic's external bulkheads, deckhouses, lifeboats, funnels etc., were painted in the standard livery of the White Star Line. Funnels were painted in a light color termed 'White Star Buff',[7] topped off with a wide band of black paint to help hide the coal smoke residue which played havoc on steam vessels. The sheer stripe, ship's name, and port of registry were painted in yellow chromate paint which had a yellow-gold hue in appearance but was not metallic.

Browns and tans appear to have been commonly used in passenger liners. In one specification for the *Lusitania*, the builder called for 'teak brown'. Since teak and mahogany were the main woods used for windows, rails, and the interiors of many ships, it would not be surprising that these companies would try and match these colors to some degree for visual continuity. On the *Olympic*-class liners, for instance, the masts, dados[8] in the forward and after Well Decks and the Third Class open space were painted in a color Harland & Wolff called 'Dark Mast'. This was a light brown according to some who have researched the color; it may have been intended to correspond to the hue of oiled teak. 'Stone', a buff color, was used inside the lifeboats, the forward cargo holds, and the quarters for the firemen, trimmers and greasers, among other areas. A variation specified as 'Light Stone' was also used in some instances about the ship. This sandy hue must have been a practical way of hiding dirt when opting not to use white, which was the color of the remaining crew's accommodations. A chocolate-brown color was used within trunkways for the hatches, and other areas of exposed steel that apparently did not need to reflect the interior lighting.

Titanic's paint colors were as follows:[9]

Paint Colors

Location	**Color**
Hull – bottom	Reddish-brown antifouling
Hull – top	Black
Hull – name & port of registry	Yellow-gold
Hull – sheer stripe	Yellow-gold
Superstructure	White
Railings	White
Bulwarks, except Well Decks	White
Bulwarks and bulkheads – Well Decks	White above, 'Dark Mast' dado
Deckhouses – exterior	White
Deckhouses – nosing where applicable	Brown
Roof – Navigating Bridge	Medium gray
Roof – Second Class elevator machinery house	Medium gray
Roof – wing cabs (covering boards)	Medium gray
Roof – Officer's Mess (covering board)	Medium gray
Skylights- over Marconi Operating Room and Officers' Lavatory	Brown to match teak
Skylights – all others	White

Lifeboats – interior	'Stone'
Lifeboats – exterior	White with brown sheer planks
Lifeboat davits	White
Funnels	'White Star Buff' with black band at top
Funnel casings (top)	Dark gray
Masts and derrick	'Dark Mast'
Crane jibs	White
Crane bases	Medium-gray tops plate with white sides, exc. 'Dark Mast' dados on Well Deck cranes
Winches – electric	Green with black whipping ends
Winches – steam	Black
Hatch coaming – No.1 Hatch	'Dark Mast' front, port & starboard sides; white on aft side to match breakwater
Hatch coaming – Nos 2,3,5 and 6 Hatches	'Dark Mast'
Hatch coaming – No.4 Hatches	White
Cargo holds	'Stone'
Waterways	Black
Rollers (Well Decks)	Black
Capstans and Bitts	Black
Fairlead rollers	Black
Interior trunks	'Dark Mast'
Bare interior decks	Gray under gratings & wood decks
Engine room and casing	White with chocolate-brown dado on bulkhead at Starting Platform
Engines (main engines, steering and warping engines)	Columns – 'Light Mast;' cylinder lagging – steel gray; and auxiliary machinery underside of the cylinders in crank pits – white
Boiler rooms	Stone with chocolate-brown dado in stokeholds
Shaft Tunnel	White with chocolate-brown dado
Firemen's Tunnel	'Stone'
Steam pipe covers	Black
Gratings in machinery spaces	Black
Refrigerating machinery	White with brine pipes painted to various colors specified by manufacturer

Antifouling paint

The biofouling of iron and steel ship hulls was, and still is, a constant source of trouble for ship owners. As marine growth accumulates over the large underwater hull area, a ship's speed becomes markedly reduced, with a corresponding rise in the consumption of fuel. In ships such as *Titanic*, this meant a large additional expenditure of coal. As speed was the name of the game in 1912, fouled hulls became a serious chore to attend to. Ever since the introduction of iron ships there has been a sustained endeavor to produce a perfect antifouling paint – a composition which would be completely resistant to the attachment of seaweed and barnacles. Hundreds of methods of avoiding fouling had been tried, patented or proposed by 1912 (even before 1870, 200 patents were taken out), but a perfect one had not yet been invented, nor has there been one to this day.

Numerous patent antifouling compositions were available in 1912, but all that could be said of them is that they were more or less successful in retarding or delaying fouling, and, indeed, this was all that was really claimed or expected of them. The antifouling properties were secured by the introduction of certain chemicals that were toxic to marine growth – copper or arsenic, for example – and by giving ablative properties to the vehicle. 'Ablative' meant that the paint's surface slowly wore away over time, thereby ensuring that a fresh layer of the antifouling chemical was always exposed to the water. It was evident that a vessel's bottom, when coated with such a composition, greatly retarded the initial stages of biofouling. This includes microbes, algal

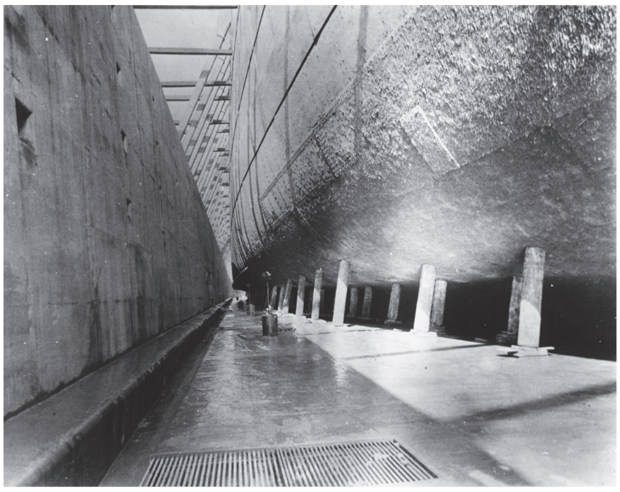


Fig. 14-10 **Fouling on Hull** – *Olympic*'s bottom after being moved into drydock from the Fitting-Out Wharf. Sitting idle in the water can foul the bottom quite a bit, as seen here. The drag created by barnacles and other marine growth can have a marked effect on a ship's fuel consumption. *(H&W/Authors' collection)*

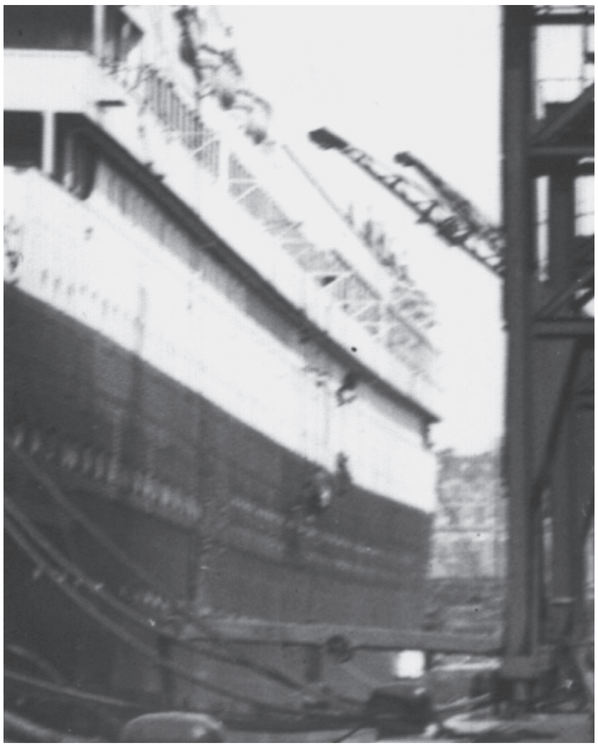


Fig. 14-11 **Touching up *Titanic*'s Paint** – At Southampton, painters suspended from *Titanic*'s side are giving her paint a final touch-up on the side facing the dock in preparation for the crowds that would see her for the first time as she departed on her maiden voyage a few days hence. The paint on the starboard side remained largely untouched.

spores, marine fungi and protozoa; and these, in seeking to attach themselves, were largely poisoned before they obtained a secure hold. It should be observed that when marine growths once secured an attachment, the poisonous nature of the paint had little effect upon them, for the attaching medium was not, like the roots of a plant, a means of nutrition, but acted merely as a mooring. In addition, the initial layer of biofouling (noted above) formed the substrate to which the macro organisms such as barnacles and limpets attached.

In theory, any antifouling compound could be rendered so highly poisonous as to destroy any organisms attempting to attach themselves, but in reality, no substance was completely effective. The success of an antifouling paint depended largely on the vessel's movements after coating, the time she spent in harbor, the length of the voyages, the particular seas navigated (temperature and concentration of marine life), the season of the year and other factors. For vessels in a regular trade and route, a composition was usually found well suited to their requirements, but the same one might be quite useless in another vessel on a different route, for it might wash off too quickly, or too slowly, or it might be insufficiently poisonous, or its antifouling qualities might not be fully developed at the right time. Passenger vessels like *Titanic* that sailed the North Atlantic needed only to be recoated once a year, whereas vessels sailing in warmer waters were sometimes recoated at the end of every voyage.

Antifouling compositions were only applied as an outer coat, on the top of red lead or other anti-corrosive paints; to apply some of them to bare plating gave very poor results. As they possessed little or no anticorrosive qualities, they would be quickly thrown off by corrosion of the plating beneath. At each dry-docking *Titanic* would have received only one coat of antifouling composition,[10] the one last applied having worn off or lost its antifouling properties, and, of course, before coating, the weeds, barnacles, limpets and loose paint would have been scraped off more or less thoroughly.

In regard to the preservation of the plating, it was sometimes desirable to chip off all the old paint and recoat the bare steel with anticorrosive paint, for after many years paint loses its properties as a protective watertight covering.

Paint was applied to *Titanic* by the use of scaffolding, bosun's chairs suspended from gin blocks or coaling outriggers, or by any other means of getting to the hard-to-reach areas. Externally, *Titanic*'s hull was painted by workers on lighters when she was afloat, or in drydock when necessary.

Cement

Portland cement was composed of chalk and clay (lime, silica and aluminum). When mixed, or 'gauged', with water into a dough, it quickly underwent a chemical and molecular change, stiffened and set. Some cement would set in ten minutes or less from the moment of mixing with water, while others took much longer – half an hour or more. The set did not leave the cement hard, it merely transformed it from a soft, wet dough into a comparatively dry solid; its surface, formerly glossy with water, became dry, and, to work it further, more water was added. The final set, or actual hardening of the cement, occurred gradually after the first set. A distinctive characteristic of Portland cement is that it hardened just as well under water, and for this reason was termed 'hydraulic cement'.

Portland cement was extensively used in the shipyard. As a wash, it formed a substitute for paint; and as a thick layer or paving, it protected the bottom plating from attrition as well as from corrosion. As a wash, it was mixed with water to the consistency of thin glue and applied with brushes. It was used in this form for coating the floor plates, etc., in the bilges below the ceiling plating and for the interiors of double bottoms. Owing to the damp and foul surroundings of the bilge, oil paint was difficult to apply and would not last long, whereas when cement wash was applied to wet plates it could be put on expeditiously by laborers, and it hardened even when immersed in water.[11]

For the interiors of double bottoms, oil paint was inadvisable because, apart from the damp surroundings, the fumes from the paint would asphyxiate the men during its application. Portland cement, on the other hand, was thought to purify the air and have antiseptic properties, so much so that it was sometimes used as a substitute for lime for coating the interior of drinking-water tanks. Unlike paint, it was not impervious to water; nevertheless, as it was alkaline, it had a markedly deterrent effect on corrosion (iron will not rust in lime water). In time, however, it lost this property, and required frequent renewal. It was usually applied in a single coat, but a double one gave better and more enduring protection.

The most important application of Portland cement was its use as a protective layer or paving on the inside of the bottom plating, for which purpose it was mixed with sand as a mortar. When thus applied it not only protected the plating against the corrosive effect of foul bilge water, but against the erosive action of any hard substance which washed about within it.

On vessels of the day, the cement on the bottom was usually thin, and worked up as a filler over the frame rivets. In fact, the hard-to-reach pockets in *Titanic*'s hull at the bow and stern were filled with cement. If these confined and inaccessible spaces were not filled with cement, dirt would accumulate and cause continuous and unobserved corrosion.

Cement had other applications aboard ships as well. It was used as a protective paving for the stringer plate in gutter waterways and for the deck plating in the water closets, lavatories, and bathrooms which were cemented and tiled. When there were several water closets or bathrooms in a group, the wood coamings of the partitions were elevated above the tiles by fixing them to deep angle- or Z-lugs riveted to the plating. This kept them clear of water and permitted the floor to be washed by a hose in one operation, with the floor drained by a single scupper. The floors of the tank rooms on the Boat Deck and A Deck were cemented for obvious reasons. Cement was commonly used for filling the trough-like spaces between the frames at the sides of the 'tween decks, and for sealing watertight flats and watertight shoes. It was sometimes used as a substitute

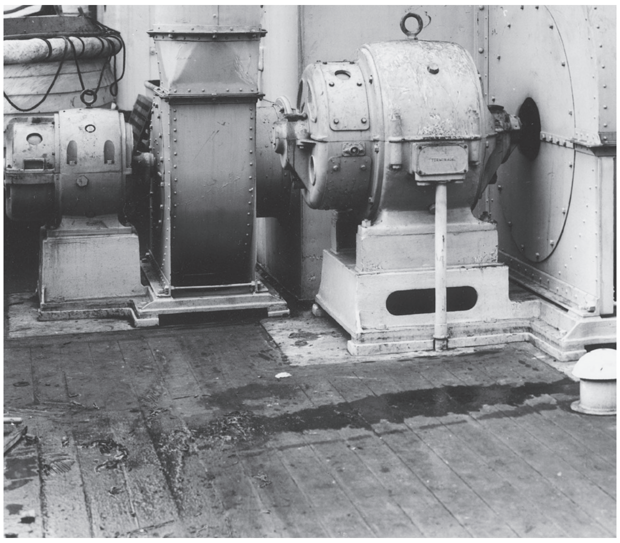


Fig. 14-12 **Ventilator Footing** – Cement was used as a footing material for the ventilators on *Titanic* and other ships of the era. *(H&W/Authors' collection)*

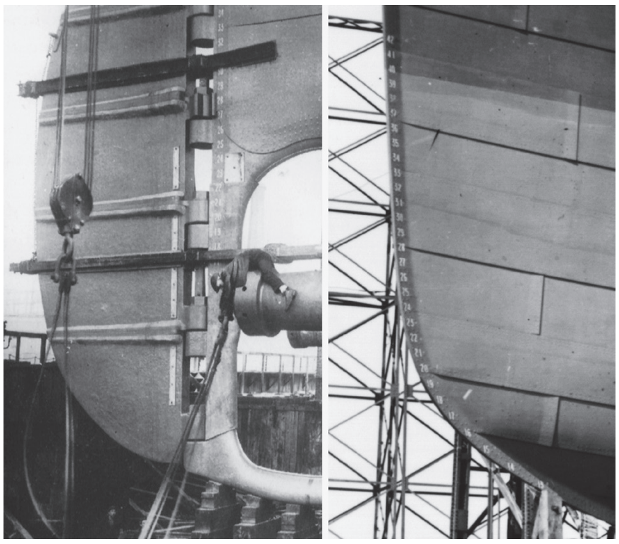


Fig. 14-13 **Draft Numbers** – *Titanic*'s stern frame and stem, showing the draft numbers. *(Both images H&W/Authors' collection)*

for wooden wedges at the heels of the masts, and for the deck plank next to the hot machinery casing. Cement was the answer to many problems, and consequently, *Titanic* had her share of this substance about her decks. It could even be seen as the footing for ventilation fans and winches on the weather decks.

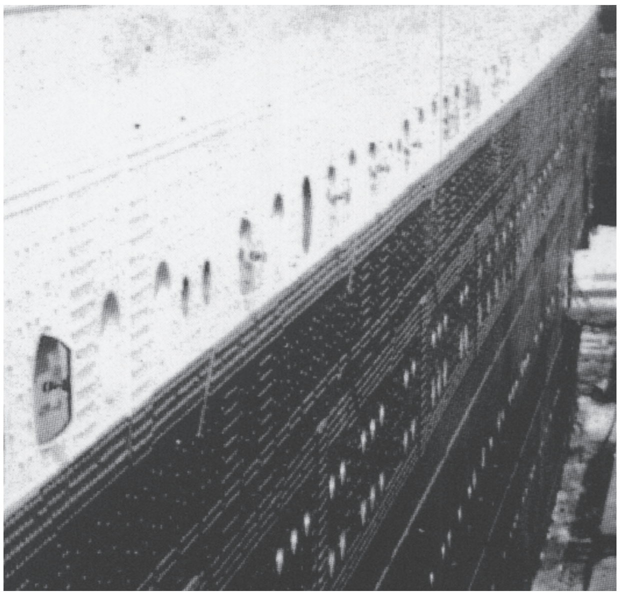


Fig. 14-14 **Sheer Stripe** – The *Olympic*-class liners had a sheer stripe painted in yellow chromate at the top edge of the hull. It can be seen here spanning several rows of rivets between the black of the hull and the white of the superstructure. This was a departure from most other White Star Line ships of the era, on which the stripe was usually placed several feet below the top edge of the black. *Olympic*'s sheer stripe would be lowered to match the rest of the fleet in 1921. *(Father Browne photograph/ Authors' collection)*

SHELL MARKINGS

Draft numbers

The hulls of steamers and sailing vessels were required by the British Board of Trade to have certain markings to indicate the ship's draft, port of registry and of course the ship's name.

'Displacement' is the actual weight of the entire vessel and all that is in her. It is indicated in long tons (a long ton being 2,240lb) and of course varied with the draft of the vessel. 'Heavy displacement' is the displacement when a vessel is completely loaded, cargo and bunker spaces filled, and the vessel is down to her deepest draft mark. The displacement measurement is most useful in the loading and trimming of vessels through the use of a displacement curve[12] and the tons-per-inch scale. All steamers were supplied with this curve and scale, and from it, the weight of the vessel could be taken by reading the draft fore and aft, taking the mean and setting it off on the scale.

To arrive at the displacement of a merchant vessel such as *Titanic* with a fair degree of accuracy, one had to estimate the block coefficient if not known. The block coefficient is the ratio of the volume of that part of the ship that is underwater to the volume of a block having a length, breadth, and depth equal to the length, beam and draft of the vessel under consideration.

The draft was taken at the bow and stern. The draft numerals were cut into the steel on both sides of the stem and sternpost, located accurately with regard to their vertical position. The numerals were of Arabic-style font, 6in high, and painted white. The base of the numeral rested on the even foot. Additional inches of draft above the even foot mark were estimated by eye.

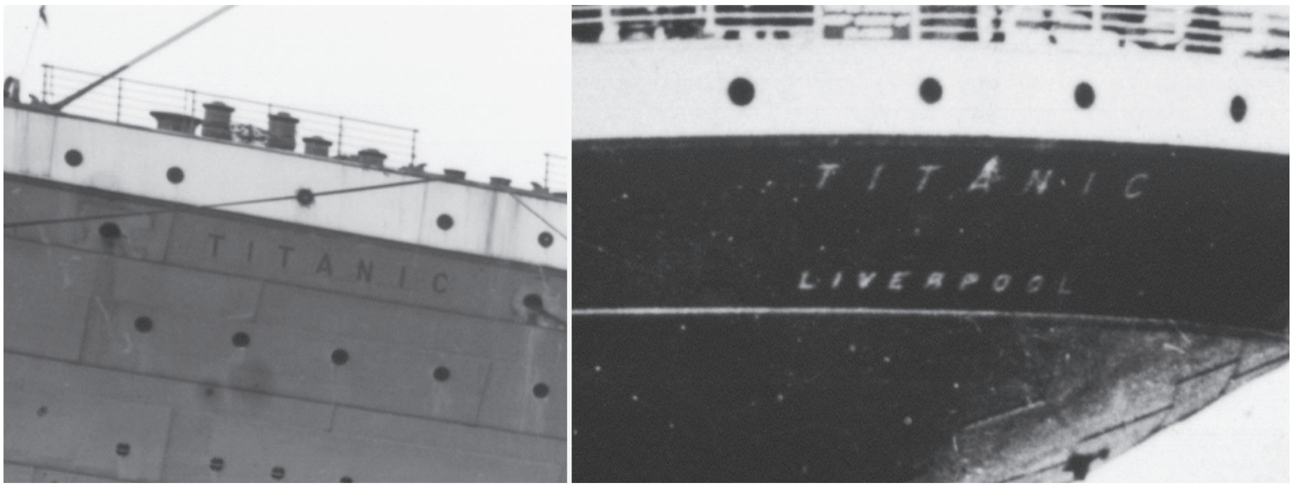


Fig. 14-15 **Name and Port of Registry** – The name on *Titanic*'s bow as seen during construction, and the name and port of registry as seen off Queenstown. In old black-and-white photographs of this era, the yellow color of the lettering is generally very difficult to discern against the black paint, but these two images are exceptions. The photograph taken from astern does not show the sheer stripe, but the words stand out as if they were white. This indicates that the sun was reflecting off the water just at the right angle to expose them to view. *(Both images authors' collection)*

Sheer stripe

The sheer stripe was painted on the shell plating just below the white of the superstructure and the sheer strakes at the forecastle and stern. It was 10¼in wide, tapering at the bows and stern of the ship. Special detailing cut or ground into the surface of the shell plates provided permanent guidelines for cutting the paint line for the sheer stripe. It is unknown whether this was done to the plates before or after they were in place on the hull while she rested in her construction berth.

Name and port of registry

The ship's name at the bow and stern, along with the port of registry, were etched into the plates. In general practice, the letters of these words would be only outlined and the steel within the outlines painted. However, on *Titanic* and her sisters, the letters were fully etched in. As with the cutting of the guidelines for the sheer stripe, it is still unknown whether this was done to the plates before or after they were in place on the hull. The letters spelling the ship's name at the bow and stern (TITANIC) were 18in in height, while the letters of the ship's port of registry (LIVERPOOL) were 12in in height.

Freeboard markings

The freeboard of a vessel is the height of the side above water level, measured at amidships from the top of the freeboard deck;[13] the distance being determined in accordance with the freeboard tables. Under the British Regulations, the measurement was actually made from a line called a 'statutory deck line', which was placed above the top of the freeboard deck.

The subject of loading a vessel is closely connected to the name of Samuel Plimsoll, who, as a member of Parliament, conducted a strong campaign in the early 1870s for the fixing of load lines on vessels under the British flag. In Plimsoll's opinion, the unusual number of disasters at sea that had been occurring for years were due chiefly to the overloading of vessels, and he contended that Parliament should establish a load line for every vessel.

The Merchant Shipping Act of 1876 required that a circular disk, with a line drawn through the center, should be painted amidships on both sides of every British vessel, except those under 80 tons GRT engaged in coastal trading. This mark, which came to be known as the Plimsoll mark, was to indicate the greatest draft to which vessels should be loaded. Although it was the duty of the Board of Trade to see that no overloaded vessel cleared any port, it was still up to the ship owner to fix the load line. This indefinite method of procedure led to many disputes, but no further action was taken until 1890 when it was decided that the fixing of load lines should be based upon a more definite and scientific scale. Accordingly, in that year the Load Line Act was passed. This act provided that load lines should be marked in accordance with regulations provided by the Board of Trade, and that the position of the disk should conform with the tables fixed by the Load Line Committee. This act was reiterated in the Merchant Shipping Act of 1894.

Draft markings

Located amidships at the waterline was the Plimsoll line, which was cut into the ship's side and painted per regulation. This marking appeared on both the port and starboard sides of the hull and was utilized to measure the draft of the ship or freeboard. It was a white ring 12in in diameter on the outside (10in in diameter on the inside) with a white line 18in long by 1in in width, passing through the center horizontally. This was further marked by a 'B' on one side of the disc and a 'T' on the other, these initials standing for Board of Trade. There was also a vertical line 21in forward of the center of the disc from which horizontal lines, 9in in length, projected. The upper line was marked 'FW' and represented the maximum depth to which the vessel could be loaded in fresh water. The 'FW' line was marked abaft the vertical line; the other lines, marked forward of the vertical line, were 'S' for summer (in salt water), and below that, 'W' for winter (in salt water).

In addition to the above, it was required that *Titanic* be painted with white horizontal lines, 12in long by 1in in width, at every deck level up to and including the freeboard deck. (In addition to the required markings, the positions of the Saloon (D) and Shelter (C) Decks were marked as well.) The line indicating each deck was to have the upper edge level with the upper edge of the deck plank next to the waterway. These lines were located in line vertically with the Plimsoll line.

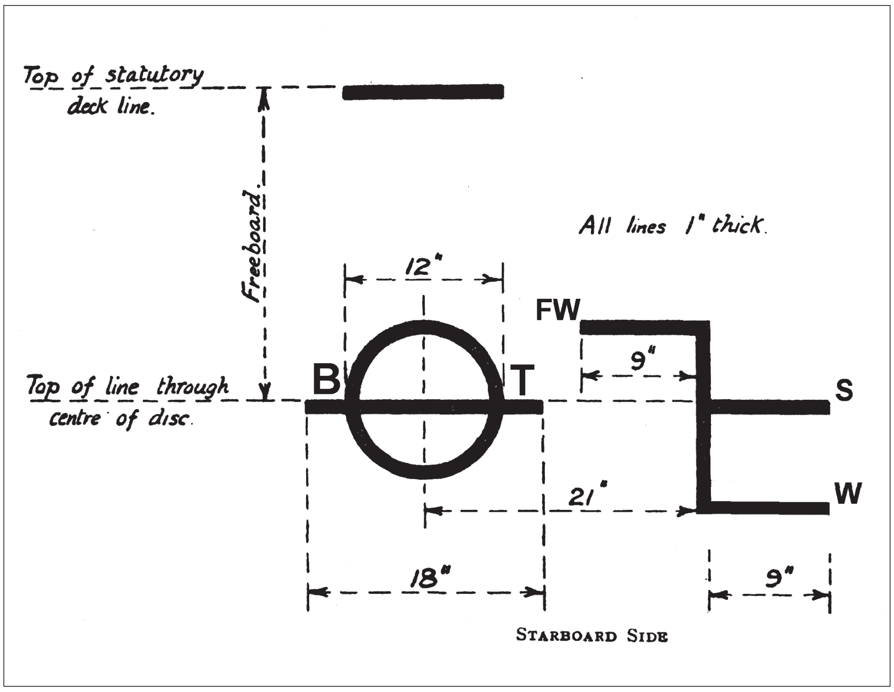
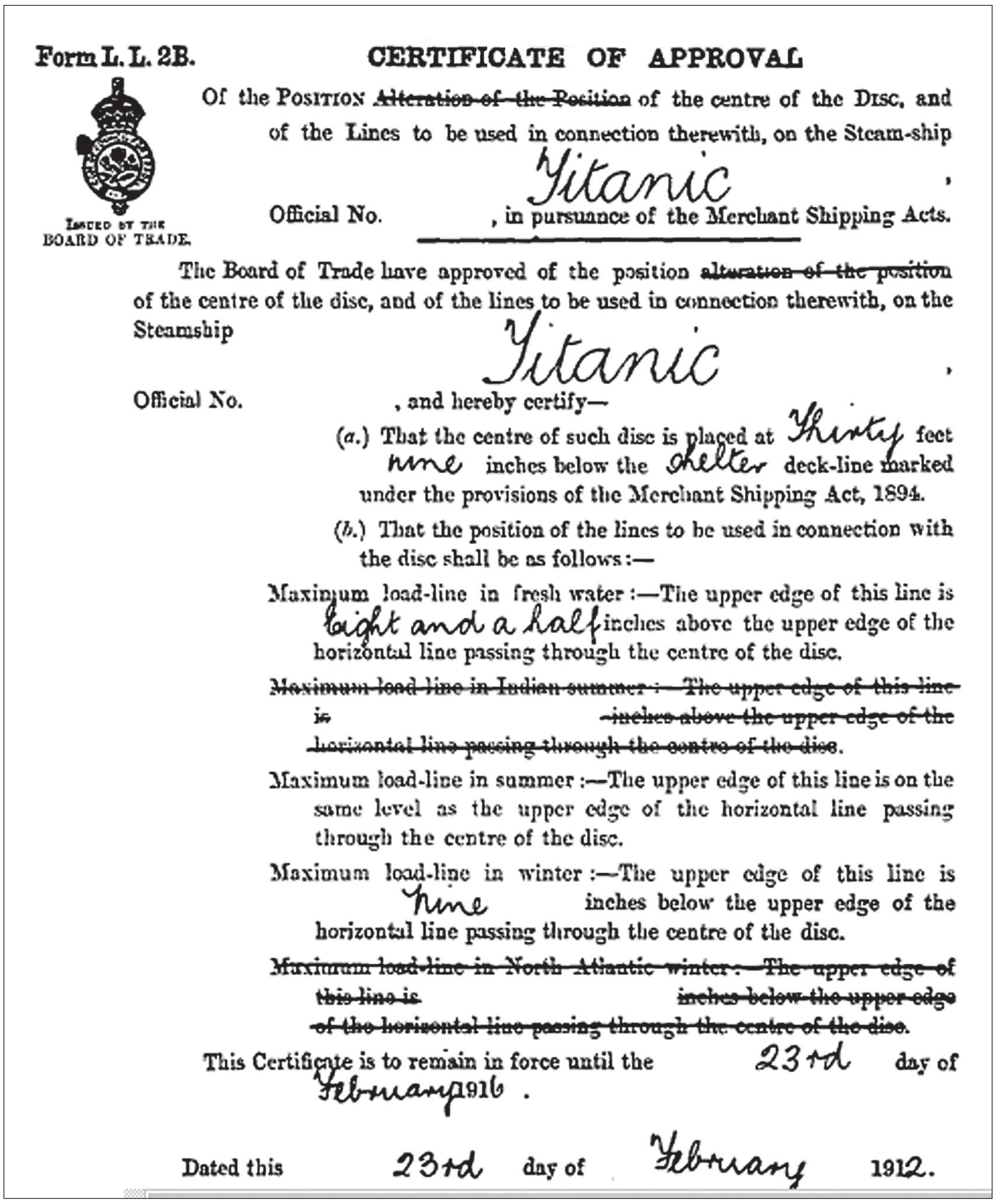

Top of statutory deck line.
Freeboard.
All lines 1" thick.
12"
FW
9"
B
T
S
Top of line through centre of disc.
21"
W
18"
9"
Starboard Side

Fig. 14-16 **Plimsoll Mark** – The Plimsoll mark as it appeared on *Titanic.* There were several variations to the letters on each side of the disk. More often than not, one would see 'L' and 'R' on British ships as this stood for a Lloyd's Register classification. Also, the letters for indicating the maximum permitted load draft in different waters depended on where the ship was expected to operate. For instance, there was a marking for 'IS,' or Indian Summer; this applied to the fine-weather months in the waters between the Suez and Singapore. There was also a 'WNA' which meant 'Winter North Atlantic.' Photographs show that *Titanic* and her sisters were marked with only the standard 'FW' (Fresh Water) line, 'S' for salt water in summer (April through September), and 'W' for salt water in winter (October through March).



Form L. L. 2B. **CERTIFICATE OF APPROVAL**

ISSUED BY THE BOARD OF TRADE.

Of the POSITION ~~Alteration of the Position~~ of the centre of the DISC, and of the Lines to be used in connection therewith, on the Steam-ship Titanic, Official No. , in pursuance of the Merchant Shipping Acts.

The Board of Trade have approved of the position ~~alteration of the position~~ of the centre of the disc, and of the lines to be used in connection therewith, on the Steamship Titanic, Official No. , and hereby certify—

(*a.*) That the centre of such disc is placed at Thirty feet nine inches below the Shelter deck-line marked under the provisions of the Merchant Shipping Act, 1894.

(*b.*) That the position of the lines to be used in connection with the disc shall be as follows:—

Maximum load-line in fresh water:—The upper edge of this line is Eight and a half inches above the upper edge of the horizontal line passing through the centre of the disc.

~~Maximum load-line in Indian summer:—The upper edge of this line is inches above the upper edge of the horizontal line passing through the centre of the disc.~~

Maximum load-line in summer:—The upper edge of this line is on the same level as the upper edge of the horizontal line passing through the centre of the disc.

Maximum load-line in winter:—The upper edge of this line is nine inches below the upper edge of the horizontal line passing through the centre of the disc.

~~Maximum load-line in North Atlantic winter:—The upper edge of this line is inches below the upper edge of the horizontal line passing through the centre of the disc.~~

This Certificate is to remain in force until the 23rd day of February 1916.

Dated this 23rd day of February 1912.

Fig. 14-17 **Load Line Certificate** – The Load Line Certificate as approved for *Titanic.* *(National Archives/Authors' collection)*

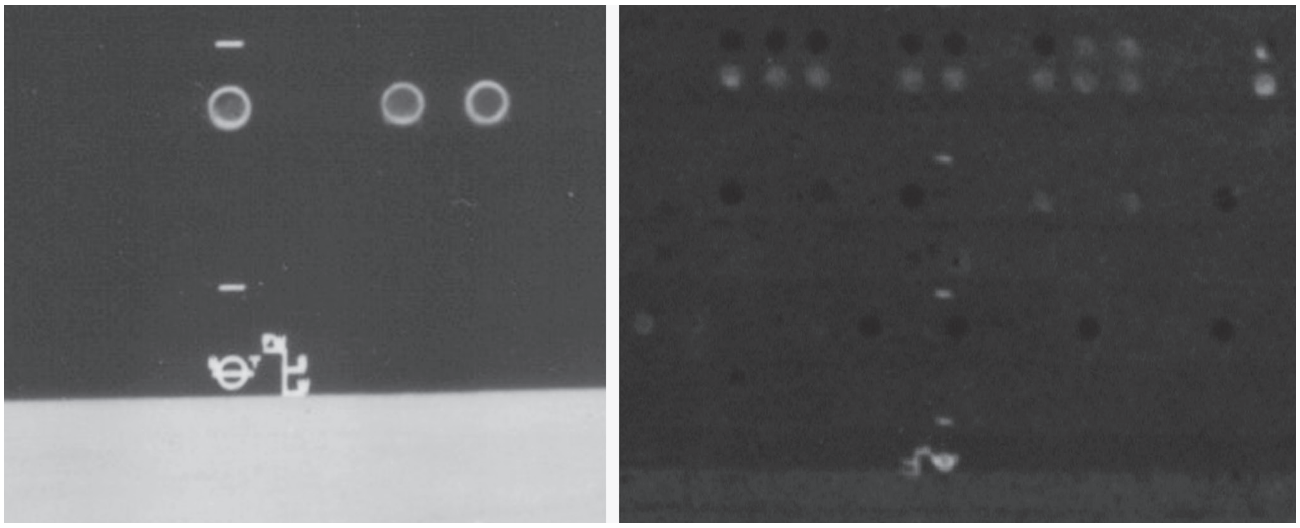


Fig. 14-18 **Plimsoll Mark** – At left, the Plimsoll mark and freeboard lines as seen on the builder's model of *Britannic* at Harland & Wolff. At right, an enlargement of the side of *Olympic*'s hull, showing the markings and the individual lines at each deck. *(Both images authors' collection)*

Notes

1. Carbonic acid is a weak acid that results from carbon dioxide dissolving in water.
2. Harland & Wolff would go so far as to specify that the final two coats of paint on the hull topside was to be one coat of lead color and one coat of black, both non-poisonous.
3. The Tank Top, the coal bunkers, and the areas below the floors of the stokeholds and tunnels were covered with a bituminous solution that was like a black varnish resembling tar, which was impervious to water.
4. Litharge is an oxide of lead, yellow in color.
5. The use of buttermilk, with bright ochre, was discovered by British shipping engineer Robert Napier in searching for a heat-resistant funnel paint. He discovered that adding buttermilk would not only make the paint heat resistant, but would cause it to be baked onto the steel and make it very durable. The resultant orange/red color would become the trademark of the Cunard line.
6. Dark red was the common color for interiors of ventilators on many vessels; however, White Star used white paint for ventilator interiors. This is a common mistake made by hobbyists who paint the cowl mouth openings red on their *Titanic* models.
7. 'Buff' was a common descriptive term for many similar funnel colors used by various shipping lines. It is unknown if the term 'White Star Buff' was a period term to denote the White Star's funnel color as being different than the 'standard' buff color, or if the term was coined by steamship aficionados much later in history.
8. The term 'dado' is an architectural term, referring to the lower portion of a wall when decorated differently from the upper part. In this case, it referred to the lower areas of the Well Decks, Well Deck crane bases, ventilators, etc. which were painted a dark color.
9. With the exception of the colors 'Stone', 'Dark Mast', 'Stone', 'Light Stone' and 'Light Mast,' all colors are general descriptive terms intended to indicate the general color only. They are not official color designations by either Harland & Wolff or White Star.
10. Harland & Wolff used antifouling paint made by Suter-Hartmann & Rahtjens for some of their ships, and this may have been the case for *Titanic* also.
11. Harland & Wolff also had their own custom mixture which was widely used aboard their ships; this consisted of cement, sand, and coke breeze (the refuse remaining from the manufacture of coke).
12. A displacement curve is a curve showing what the displacement of the vessel would be, floating at any given draft.
13. The 'freeboard deck' was the highest continuous deck to which all of the watertight bulkheads rise. On *Titanic*, this was E Deck.

Chapter 15

The Propelling Machinery

Background: The Decision to Employ Combination Machinery

The beginning of the twentieth century was a time of rapid evolution in the field of marine engineering. As new technologies developed, they were quickly applied even if not developed to their full potential. Such was the case with the marine steam turbine. Though the turbine was beginning to show potential for producing considerable power in comparison to its size and weight, it was still many years away from becoming an economical prime mover for merchant shipping of more moderate speed and power requirements. For ships operating within these parameters, triple- and quadruple-expansion reciprocating engines were still returning the same or slightly higher economy, while costing considerably less to build than the still-novel turbines which would eventually replace them. The following table gives an indication of the relative fuel consumption for the various types of main propulsion systems in use or being developed at the time the marine engineers at Harland & Wolff were evaluating what sort of machinery to install on the *Olympic*-class liners:

Comparative Fuel Consumptions – Common Propulsion Systems *c.*1912

Engine type	Lbs/hr/SHP[1]	Fuel type
Triple-expansion steam engine	1.54	Coal
Quadruple-expansion steam engine	1.4–1.45	Coal
Direct-drive turbine at low speeds (<16 knots)	2.4	Coal
Direct-drive turbine at high speeds (>23knots) (compound – HP and LP stages)	1.5	Coal
Direct-drive turbine at high speeds (>23 knots) (triple-expansion – HP, IP and LP stages)	1.38	Coal
Combination triple-expansion engine and exhaust turbine	1.25[2]	Coal

Consistent with the White Star Line's policy of eschewing speed in favor of size and comfort, the efforts of Harland & Wolff's marine engineering department were focused on developing machinery plants of relatively moderate power in comparison to those 'Blue Ribband' contenders of White Star's competition. The main criteria in designing propelling machinery for White Star's vessels was high economy and reliability, with sufficient reserve power to guarantee that the required service speed would be maintained in even the worst conditions. Additionally, the machinery had to be as nearly vibration-free as practical. This was of utmost importance in the Line's premier ships, which were those on the transatlantic run to and from New York. By the late 1890s, Harland & Wolff had turned to triple-expansion reciprocating engines of the four-crank design, employing low-pressure cylinders at each end. This arrangement permitted much larger engines and kept the dimensions of the components of the low-pressure stage to reasonable size. Of equal importance, the four-crank arrangement allowed the application of the new Yarrow, Schlick and Tweedy system of engine balancing. Engines of this type, producing a gross 28,000 indicated horsepower (IHP), were fitted to the 17,274GRT *Oceanic (II)* of 1899, giving her a top speed of over 21 knots, though in service she was usually run at the 19½-knot service speed of running mates *Teutonic* and *Majestic*.[3]

As the nineteenth century gave way to the early twentieth century, the increase in size from one class of ship to the next came in ever-broadening leaps rather than the small incremental increases which had characterized naval architecture through the mid 1890s. In taking the leap from the *Oceanic (II)* of 1899 to the 20,904GRT *Celtic* of 1901 (the first of the 'Big Four'), Harland & Wolff's engineers had to revisit the question of how to produce sufficient power to move such large ships efficiently and economically at the moderate 17-knot maximum service speed required. Although a lower average service speed was required, *Celtic* was built for the carriage of large volumes of cargo, which resulted in her form being much fuller than that of the slender, yacht-like *Oceanic*. In this case, four-crank quadruple-expansion engines producing a gross 12,600IHP were adopted as the mode of power. This choice proved satisfactory for the *Celtic* and for the second ship of the class, the 21,035GRT *Cedric* of 1903. However, even with modifications to increase output to a gross 14,000IHP, these engines failed to the push the third of the class, the 23,876GRT *Baltic* of 1904, beyond 16½ knots. To guarantee an 18-knot service speed for the 24,541GRT *Adriatic*, the fourth of the class and the third largest ship in the world at her entry into service in 1907, she was given two larger sets of quadruple-expansion engines having a gross IHP of 16,000;[4] these remained the largest of this type produced by Harland & Wolff.[5] Given the results obtained in these previous vessels, it was becoming clear that even though quadruple-expansion engines were economical to operate, particularly in large ships of moderate speed, the trend of ever-increasing size and the resulting increased power requirements was pushing the reciprocating engine towards its practical limit in terms of size and output.

For large, high-speed passenger liners which required great horsepower, the turbine was clearly becoming the engine of choice. Ships like Cunard's *Lusitania* and *Mauretania* required better than 72,000 shaft horsepower (shp) to maintain their 25-knot service speed. Power output of this kind was practical only from turbines on multiple lines of shafting, as the size and weight of reciprocating engines capable of producing such output was prohibitive. However, higher speeds came at commensurately higher prices. In addition to the much greater initial cost of the machinery came much higher fuel consumption, often coupled with the reduced passenger- and cargo-carrying capacity associated with the finer hull lines required for high speed operation.

Turbines had already been employed in a number of transatlantic liners of more moderate speed by the end of the first decade of the twentieth century. All of these were the direct-drive type, in which each individual turbine is coupled directly to a line of shafting. While this system was very simple in construction in comparison to reciprocating engines, it was inherently inefficient at lower speeds. The speed at which both the turbine and the directly coupled propeller were run was, at best, a compromise. In order to achieve reasonable efficiency at a ship's designed speed from both the turbine and from the propeller to which it was directly connected, it was necessary to operate these units from 175 to 300 revolutions per minute (RPM). These speeds were much higher than optimum for the propeller given the state of propeller technology at the time, and yet they were still too low in respect to the velocity of the steam being supplied from the boilers to obtain good efficiency from the turbine itself.[6]

The results obtained by the Cunard Line's first experiment in turbine propulsion are illustrative of typical results obtained at the time with direct-drive turbine propulsion. In December 1903, in an effort to gain both operational and design experience with turbines, John Brown & Co. proposed the use of turbines instead of reciprocating engines when tendering a bid to build the *Carmania*, a sister ship for the twin-screw *Caronia*. Both ships were nearly identical in form and would be used under identical service conditions, their method of propulsion being the only significant difference. Whereas *Caronia* was propelled by two sets of four-crank quadruple-expansion engines of a gross 21,000IHP at 80RPM, three turbines propelled *Carmania*, each directly coupled to its own shaft. The center shaft was driven by a high-pressure turbine that exhausted into two low-pressure turbines, each driving a wing shaft. The combined output of this machinery was 21,000shp at 175RPM. The intended service speed for the pair was 18 knots.

Initially, the slight advantage seemed to be with the turbine-propelled *Carmania*. Her three turbines occupied the same space as *Caronia*'s two sets of quadruple-expansion engines, required less height within the engine space, and even realized a 5 per cent weight savings – a benefit that could be translated directly into increased cargo capacity at maximum load draft. Additionally, she showed less inclination to vibration and produced a 1-knot higher trial speed than her reciprocating-engine sister. Although these initial results seemed to indicate the superiority of turbines over the reciprocating engine, long-term running of the two ships actually produce evidence to the contrary. Leonard Peskett, naval architect to the Cunard Company, came to the conclusion after a number of years that *Carmania*'s overall fuel consumption was much greater than that of *Caronia*, and that the results obtained in service did not warrant the use of direct-drive turbines in ships of more moderate speeds.[7]

Reduction gearing, which would allow for smaller turbines running at rotational speeds as high as ten times those of direct-drive turbines, allowed the shafts to rotate within a speed range more suited to the propeller. Later on, the use of much higher steam pressures would eventually make turbine propulsion much more efficient and economical than the reciprocating engine. However, the perfection of reduction gearing capable of handling the sort of continuous high-power output required from the propulsion machinery of the typical premier passenger liner was still well in the future. Thus, Harland & Wolff found themselves faced with the daunting task of designing a propulsion plant capable of providing the sort of economy obtainable from quadruple-expansion engines at 21 knots on ships of nearly twice the gross register tonnage of the recently completed *Adriatic*.

Lord Pirrie, Harland & Wolff's Chairman, and his competitors watched with keen interest the entry into service of turbine-propelled passenger ships such as the Allen Line's *Victorian* and Cunard's *Carmania* and took note of the potential of this new prime mover. Though Pirrie and his staff were intrigued by the turbine's future potential, unlike John Brown & Co. or Swan, Hunter & Wigham Richardson Ltd, Harland & Wolff lacked a customer with a need for the new technology and therefore had no immediate need to invest the large sums necessary to enter into the field of turbine design and construction.[8] Then, in early 1907, a series of events took place that drastically changed this situation. An order was placed for two 15,000-ton liners intended for the Dominion Line's Canadian service. However, both the Dominion Line ships and their intended service route were transferred to joint White Star Line ownership by International Mercantile Marine, the mutual parent company.[9] At the time J. Bruce Ismay, Chairman of the White Star Line, signed the contract for these two ships – *Laurentic* and *Megantic* – he informed Lord Pirrie that White Star would soon be in the position to place a contract for two huge 45,000-ton liners (to be followed by a third) to compete against Cunard's *Lusitania* and *Mauretania*, which were then nearing completion.[10] Thus it happened that at nearly the same time, the need to evaluate a new method of propulsion and the perfect test bed to evaluate such a system against more conventional machinery had presented itself in the form of two identical ships.

As a result of their experience in designing the propelling machinery for the 25,541GRT *Adriatic* and her predecessors, it had become apparent to the marine engineers at Harland & Wolff that the sort of power required to operate a 45,000 ton liner at the 20+ knots needed to maintain a weekly service with three ships was beyond the practical limitations of even the largest reciprocating engines. By this time, these same engineers were aware that Cunard had proven with *Carmania* that direct-drive turbines as the solitary source of motive power were unsuited to ships of more moderate speeds. However, in addition to a much improved power-to-weight ratio, the turbine did have the one specific advantage over the reciprocating engine of being able to produce power from the expansion of low-pressure steam well into the high vacuum range that exists within the condensers. By contrast, even the most efficient reciprocating engines expanded the steam to only about atmospheric pressure, wasting a considerable amount of latent energy contained within the steam being exhausted into the condenser.

As early as 1897, Charles Parsons had worked out a plan to use the exhaust steam from reciprocating engines to produce power via a low-pressure turbine. In 1902, as an experiment to exploit the advantages inherent in each type of engine, the British destroyer *Velox* was fitted with a propulsion plant referred to as a combination system. Reciprocating engines began the process and expanded steam to about atmospheric pressure, and then the turbine continued the expansion down to the pressure in the condensers. In this system, the turbine (or turbines) generally developed about one-third of the total power. In the case of HMS *Velox*, a quadruple-screw arrangement was used with two, three-crank, triple-expansion engines, each driving the inboard shafts and exhausting into a separate low-pressure turbine coupled to an outboard shaft. Though the system proved to be reliable and economical, the British Admiralty did not continue development of the design. The first mercantile application of combination machinery was in the 9,900-ton, 13-knot *Otaki* completed by William Denny & Brothers, Dumbarton, in 1908 for the New Zealand Shipping Company. The machinery in this case was of the triple-screw arrangement with two, three-crank, triple-expansion engines, each driving a wing shaft and exhausting into a single low-pressure turbine driving the center shaft. The arrangement worked so well that the *Otaki* realized a 12 per cent reduction in coal consumption over her sister ship, the twin-screw, quadruple-expansion engine *Orari*.[11] Though the results from the Denny-built *Otaki* were not yet available to Harland & Wolff's engineers prior to undertaking their own development of this type of machinery, they were aware of the results from the Admiralty's trials with HMS *Velox*. This, and the knowledge that a well-respected shipbuilder such as Denny had evaluated and chosen to adopt this system, must have provided significant encouragement to Pirrie and his engineers.

To gain experience in the design of combination systems, as well as experience in the design, building and installation of turbines, a practical exercise was needed. With this in mind, Pirrie proposed to Ismay that the otherwise identical *Laurentic* and *Megantic* should each be fitted with a different system of propulsion. Propulsion for the *Megantic* would be the conventional twin-screw arrangement, with each shaft driven by a four-crank, quadruple-expansion engine. The *Laurentic*, however, was to be fitted with two four-crank, triple-expansion engines, each driving a wing shaft and directing exhaust steam into a single low-pressure turbine driving a central shaft, and thence into the condensers. Ismay's long-standing belief in the capability of his builder of choice was again demonstrated with his signature on the agreement to proceed.

Although Harland & Wolff had taken out a license to build Parsons turbines in November 1905, due to financial considerations nothing had been done with regard to development or manufacturing capability. With the immediate need for both empirical data and manufacturing facilities for the production of turbines, Pirrie approached John Brown & Co. in May 1907 with an offer of merger. John Brown was quick to accept and received a majority stake in Harland & Wolff as compensation. In turn, Harland & Wolff received access to John Brown's turbine technology and manufacturing facilities, as well as guaranteed continued access to a number of forgemasters, foundries and steel mills that had recently been acquired by a syndicate of shipbuilders, which included John Brown & Co. Upon completion of the merger, Harland & Wolff immediately subcontracted *Laurentic*'s low-pressure exhaust turbine on commission to John Brown & Co.[12]

After having delayed his yard's entry into the design and manufacture of turbines, Pirrie wasted little time in catching up. As marine engineers at John Brown worked on the design of *Laurentic*'s exhaust turbine, they schooled their counterparts at Harland & Wolff in everything learned through their experience with *Caronia* and *Lusitania*, as well as other turbine-propelled vessels built by their firm for the mercantile marine and the Royal Navy. Early in 1909, as construction of *Laurentic* and her machinery were nearing completion and as the preliminary design proceeded for the machinery of the new *Olympic*-class ships, Pirrie undertook the installation of the necessary equipment at the Harland & Wolff engine works to begin the manufacture of turbines. Upon completion of the initial installation of the new machinery, the turbines for the dreadnought HMS *Neptune* were subcontracted by John Brown to Harland & Wolff in order for the latter to gain production experience.[13]

Though Harland & Wolff was now in the business of building their own turbines, they still lacked the facilities to produce and machine castings and forgings of the enormous size necessary for the casing and rotor of the exhaust turbines of *Olympic* and *Titanic*. The design of these massive components was carried out by the marine engineers at Harland & Wolff, and the patterns for the castings were made by the yard's pattern shops, but John Brown & Co. was subcontracted to provide the castings, forgings and machine work, with final machining and assembly to be carried out at Belfast. The lack of the facilities necessary to build turbines of this size and class did not persist for very long, as Lord Pirrie embarked upon a massive expansion of both the Engine Works and Foundry Shops as part of major additions to the entire Queen's Island Works, these additions being completed in the late summer of 1912. In these new shops, the complete fabrication and machining of all components for the exhaust turbine for *Britannic* was carried out – the largest turbine of this type ever constructed – and, in an interesting turnabout from the original working arrangement between Harland & Wolff and John Brown & Co., the latter firm subcontracted the former to provide the castings for the turbines of the Cunard liner *Aquitania,* then building at Clydebank.

Work commenced on the design of *Olympic* and *Titanic* following the 'Order to Proceed' filed on April 30, 1907.[14] The basic hull design and the layout of propelling machinery was decided early in the process and after numerous preliminary iterations, approval of the overall initial design by White Star directors followed on July 29, 1908.[15]Although no hard data would be available until operational experience had been gained with the *Laurentic*, Harland & Wolff was sufficiently confident in the data obtained to proceed with the design of the main engines and their supporting auxiliaries. Though a calculated risk, this was necessary to guarantee sufficient lead-time for the patternmakers and foundry to produce the raw castings and forgings required by the Engine Works. Without a sufficient lead-time, there would be unacceptable delays in completing and fitting the machinery. Since *Laurentic* was scheduled to enter service at the end of April 1909, there would be but a short period of time to correct any deficiencies and include minor to moderate design modifications into *Olympic*'s machinery. More serious modifications would have to wait until production began on *Titanic*'s machinery, the castings and forgings for these having only just been ordered at the time of *Laurentic*'s entry into service.

In the end, if there were any serious doubts or concerns on the part of Harland & Wolff or the White Star Line regarding the decision to adopt the combination system of propulsion machinery, the data gathered from *Laurentic*'s first several months in service dispelled them all. *Laurentic* proved to be very fuel efficient in comparison to other ships of similar size and speed in White Star's fleet. However, the true test came following the entry into service of her sister ship *Megantic* on June 17, 1909. *Laurentic* consistently turned in fuel consumption reports ranging from 12 per cent to 15 per cent better than those of the quadruple-expansion-engined *Megantic*. And, in addition to being more economical to operate, *Laurentic* was found to be slightly faster than her conventionally powered sister.[16]

With their prototype installation performing beyond their best expectations, Harland & Wolff's marine engineering department forged ahead on the completion of the machinery for the *Olympic*-class liners. At the same time, more modest combination machinery plants were designed and installed in ships being built for the Aberdeen Line and the Royal Mail Steam Packet Co. and other Harland & Wolff customers. In archival photographs from the Engine Works, machinery for Aberdeen's *Demosthenes* and for Royal Mail's *Arlanza* may be seen under construction alongside the machinery for *Olympic* and *Titanic*, respectively.

Information contained in Harland and Wolff's archives[17] indicates that the original design criteria for *Olympic* and *Titanic* specified a conservative estimated coal consumption figure of 825 tons per day with the engines producing an estimated 51,000HP at 21 knots. This would have given a consumption of 1.48lb/HP/hr, a figure that would have been beyond the capabilities of large quadruple-expansion engines of adequate horsepower to move such a large vessel at such speed. In practice, however, *Olympic*'s actual coal consumption proved to be a different matter, as trials determined that there was a considerable reserve of power available beyond the original design figures. It was also discovered that the average speed of 21 knots could be achieved at something just over 46,000 HP in ideal weather. At the completion of the westbound portion of *Olympic*'s maiden voyage, Ismay excitedly sent the following cable back to Lord Pirrie: '*Olympic* is a marvel, and has given unbounded satisfaction. Once again accept my warmest congratulations. Will cable you particulars speed, consumption later.' These figures, which both Ismay and Pirrie guarded closely, must have been of particular delight to both men. In five days, fifteen hours and two minutes, at an average speed of 21.7 knots, *Olympic* had consumed a remarkably low 3,540 tons of coal with an average consumption of just under 1.25lb/HP/hr.[18, 19] Such low fuel consumption, combined with superior passenger accommodations for all classes, a greater overall number of available berths and much greater cargo capacity gave the White Star Line a considerable competitive edge over their rivals at Cunard.

Further per-unit improvements were achieved in this and all types of machinery with the later introduction of oil fuel, which, in addition to numerous other benefits, guaranteed an even, consistent and easily adjusted rate of firing. Through the 1920s, the advent of single and double reduction gearing suitable for higher power output, as well as the gradual shift to watertube boilers, produced increasingly higher pressures and higher evaporation rates. This eventually resulted in coal consumptions of well under 1lb/HP/hr, with similar reductions in fuel consumption realized in oil-fired systems as well. The initial low first-cost and reasonable economy of the combination machinery system continued to make it a popular choice for intermediate class ships and passenger vessels operating at moderate speeds for Harland & Wolff and several other builders into the late 1920s.[20]

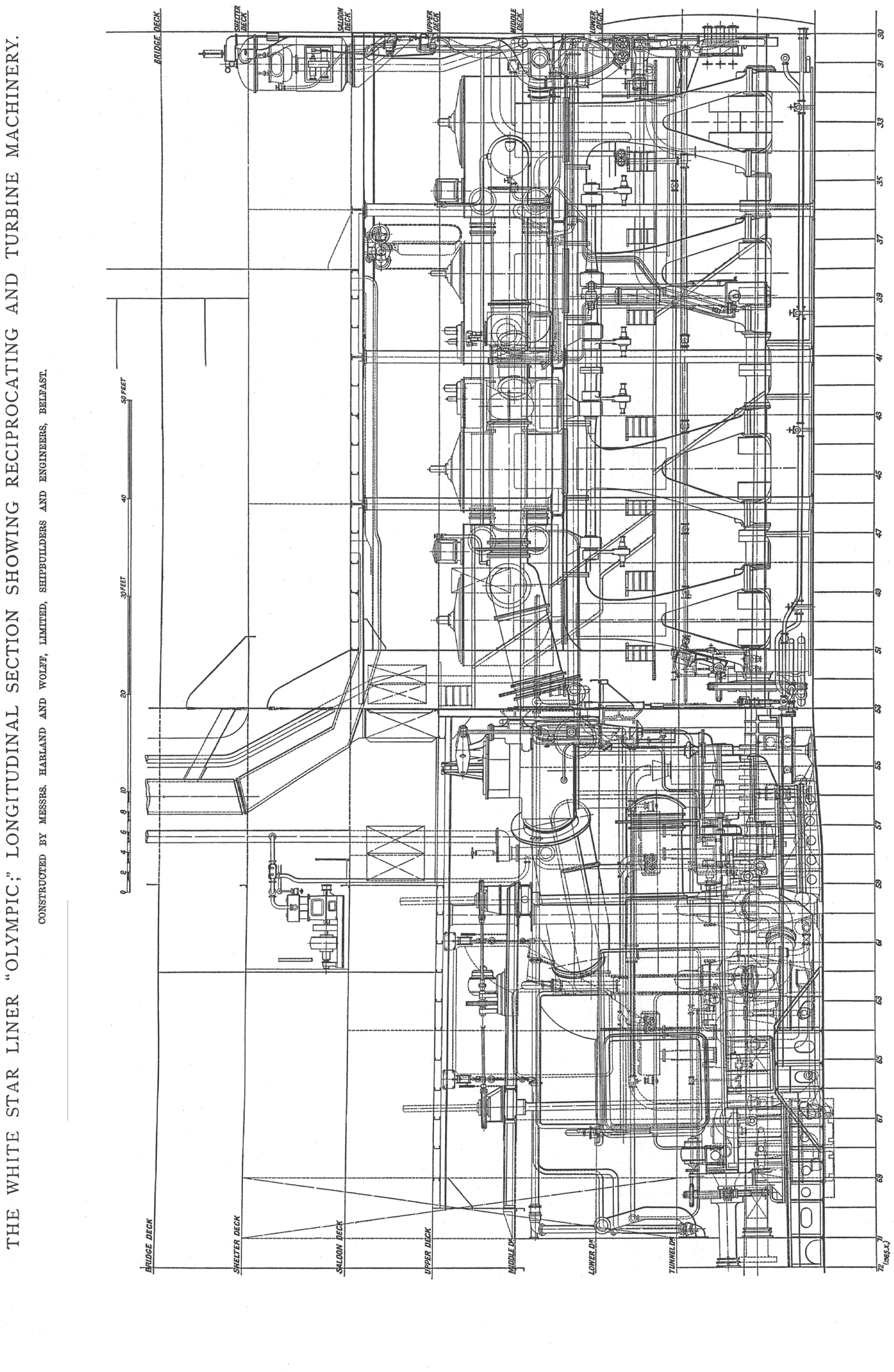
Arrangement of machinery

As will be seen from the General Arrangement plans of the ship as well as the elevations, sections and plans of the boiler and engine rooms, nearly the entire space beneath the Upper Deck (E) was occupied by the steam generating plant, coal bunkers and propelling machinery. The boiler installation and bunkers occupied six watertight compartments throughout the midbody of the vessel over a total length of 320ft.

As already stated, *Titanic* was a triple-screw steamer, each wing propeller being driven by a set of reciprocating engines and the central propeller by a low-pressure turbine. Because of the massive size of these engines, it was necessary to place the turbine in a separate compartment abaft the Reciprocating Engine Room and separated from it by a watertight bulkhead.

The Reciprocating Engine Room was placed immediately abaft the aftermost boiler room (No. 1) and occupied the space between WTBs K and L at frames 30A and 53A respectively, a length of 69ft. In addition to the reciprocating engines, this compartment contained a large amount of auxiliary machinery. In the wings were located the main feed pumps; the hotwell, bilge, sanitary, ballast and fresh water pumps; the auxiliary condenser and its circulating and air pumps; and the surface feed heater and direct-contact feed heater. The direct-contact feed heater was placed high up in the engine room casing at the centerline. Located on the port side was the extensive refrigerating plant, with the two steam-driven duplex CO_2 compressors located at the floor level of the Engine Room, and the evaporators and brine circulating pumps located in an insulated room at the level of the Orlop Deck. Above this, at the Lower Deck (G) level, was located the Brine Tank Room and a flat containing the engine lubricating oil tanks, as well as a Paint Storage Room and an Engineer's Store. Also on this level, located on a flat on the starboard side was the Engineer's Workshop which was well-equipped with the latest machine tools; ahead of this was a second Engineer's Store.

The Turbine Engine Room, the after end of which was located at WTB M on frame 71A, occupied a further length of 54ft. In addition to the low-pressure turbine,


THE WHITE STAR LINER "OLYMPIC;" LONGITUDINAL SECTION SHOWING RECIPROCATING AND TURBINE MACHINERY.
CONSTRUCTED BY MESSRS. HARLAND AND WOLFF, LIMITED, SHIPBUILDERS AND ENGINEERS, BELFAST.
0 2 4 6 8 10 20 30 FEET 40 50 FEET
BRIDGE DECK
SHELTER DECK
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
BRIDGE DECK
SHELTER DECK
SALOON DECK
UPPER DECK
MIDDLE DK.
LOWER DK.
TUNNEL DK.
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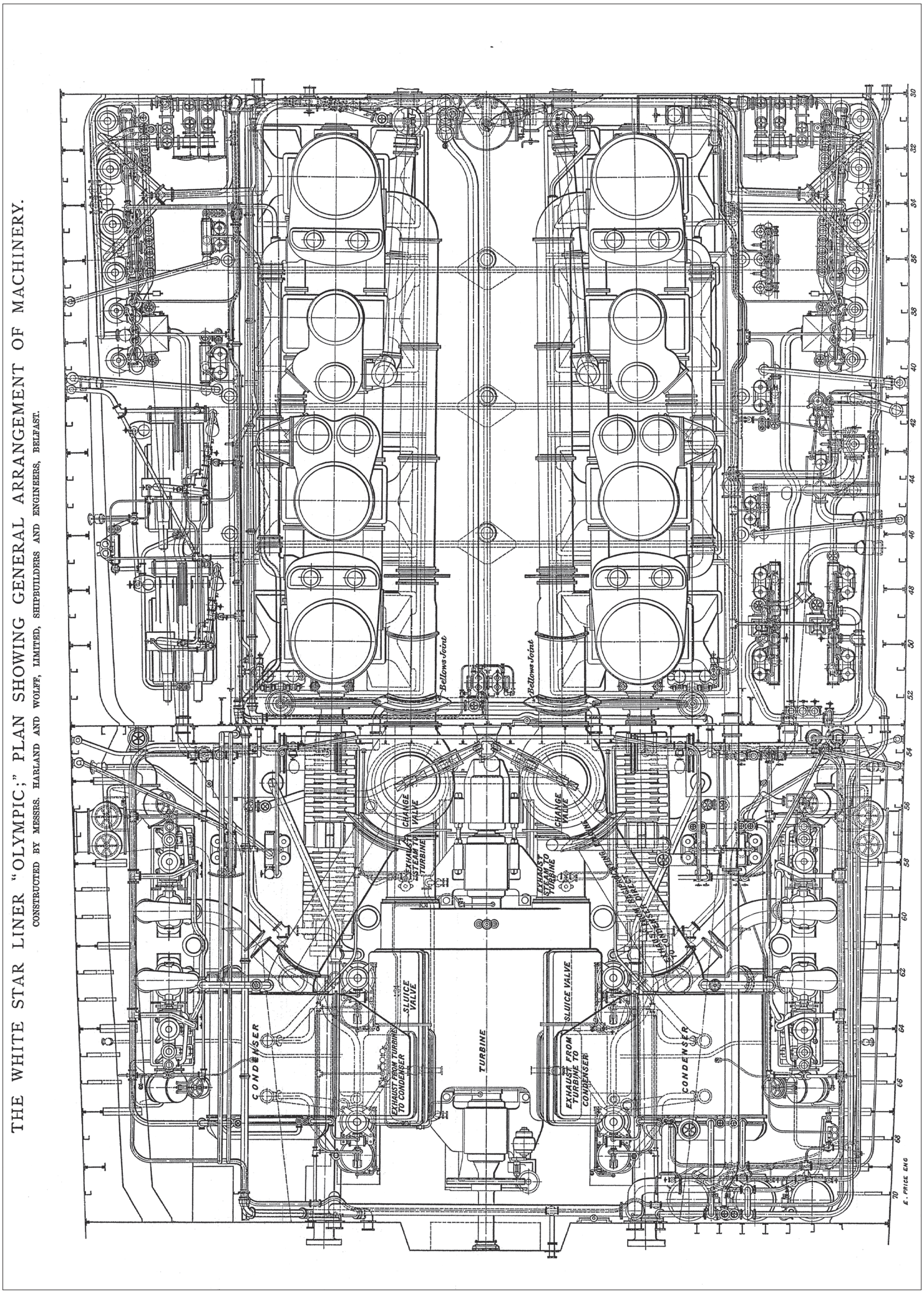
72

Fig. 15-1 **Engine Rooms** – Inboard profile.


THE WHITE STAR LINER "OLYMPIC;" PLAN SHOWING GENERAL ARRANGEMENT OF MACHINERY.
CONSTRUCTED BY MESSRS. HARLAND AND WOLFF, LIMITED, SHIPBUILDERS AND ENGINEERS, BELFAST.
Bellows Joint
Bellows Joint
CHANGE VALVE
CHANGE VALVE
EXHAUST STEAM TO TURBINE
EXHAUST STEAM TO TURBINE
SLUICE VALVE
SLUICE VALVE
CONDENSER
CONDENSER
TURBINE
EXHAUST FROM TURBINE TO CONDENSER
EXHAUST FROM TURBINE TO CONDENSER
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E. PRICE ENG

Fig. 15-2 **Engine Rooms** – Plan view.

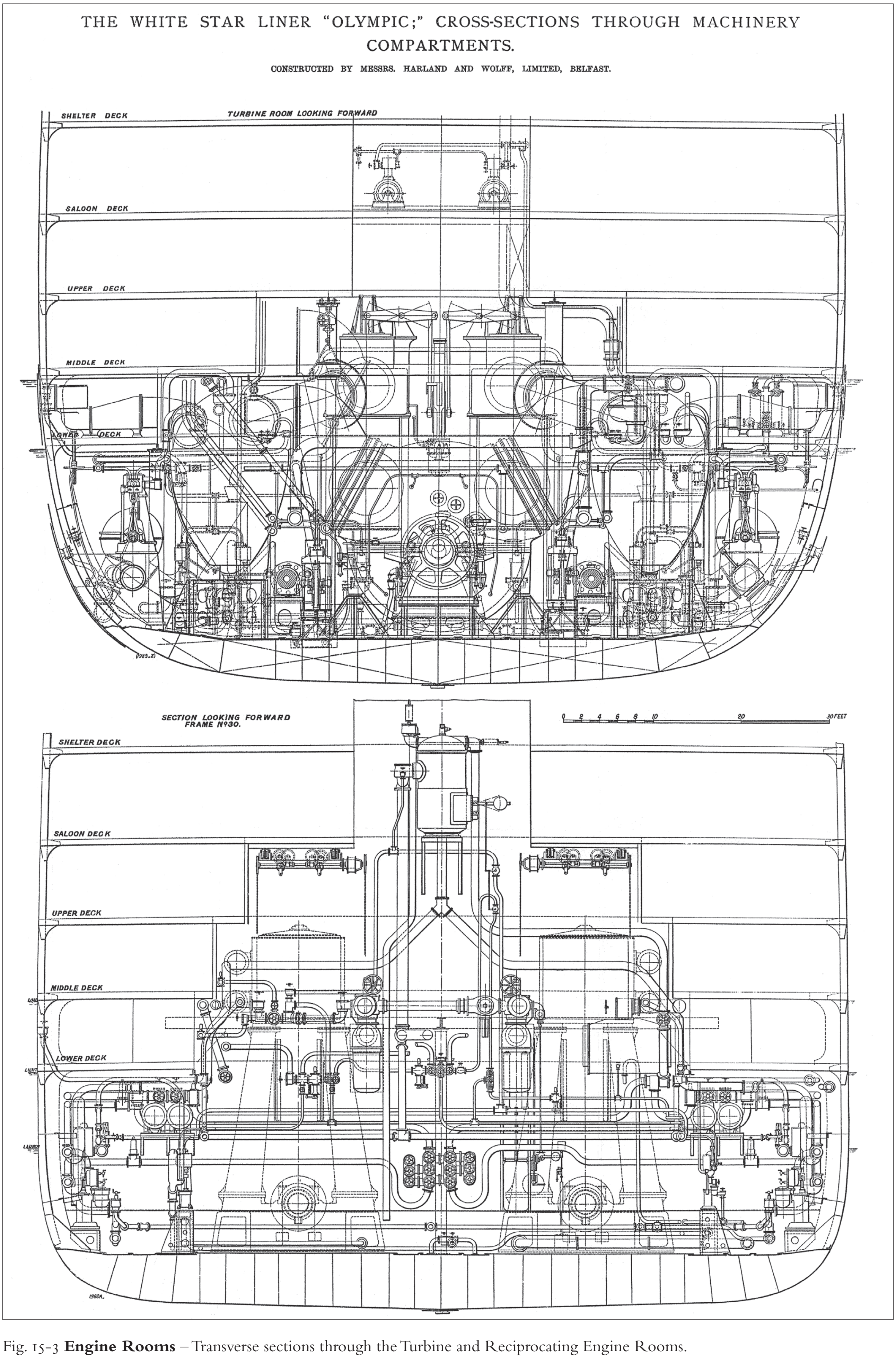
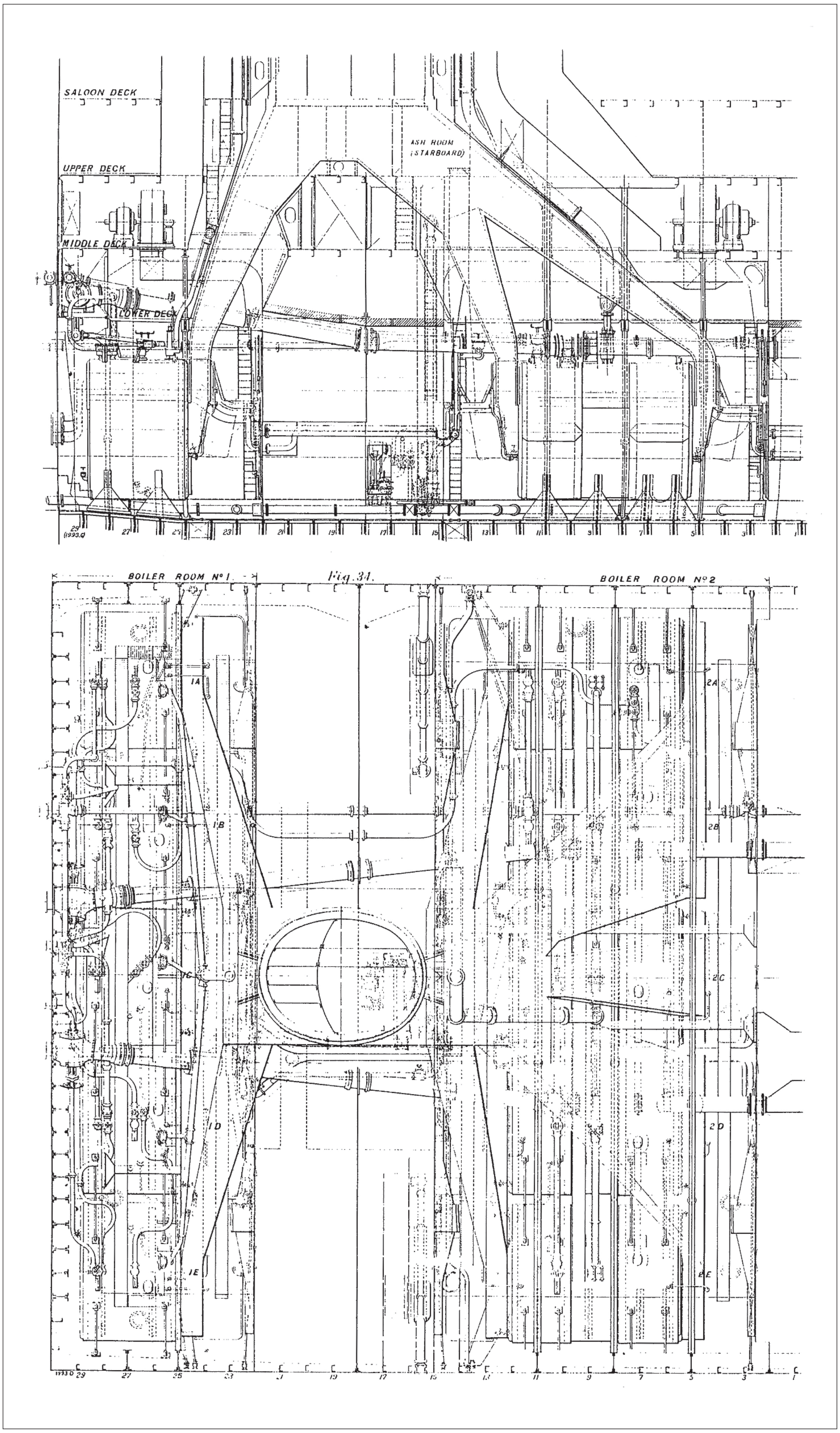

THE WHITE STAR LINER "OLYMPIC;" CROSS-SECTIONS THROUGH MACHINERY COMPARTMENTS.
CONSTRUCTED BY MESSRS. HARLAND AND WOLFF, LIMITED, BELFAST.
SHELTER DECK
TURBINE ROOM LOOKING FORWARD
SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
SECTION LOOKING FORWARD FRAME Nº30.
0 2 4 6 8 10 20 30 FEET
SHELTER DECK
SALOON DECK
UPPER DECK
MIDDLE DECK
LOAD
LOWER DECK
LIGHT
LAUNCH

Fig. 15-3 **Engine Rooms** – Transverse sections through the Turbine and Reciprocating Engine Rooms.


SALOON DECK
UPPER DECK
MIDDLE DECK
LOWER DECK
ASH ROOM (STARBOARD)
BOILER ROOM Nº 1.
Fig. 34.
BOILER ROOM Nº 2
1A
1B
1C
1D
1E
2A
2B
2C
2D
2E
29
27
25
23
21
19
17
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13
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5
3
1

Fig. 15-4 **Boiler Rooms** – Inboard profile through Nos 1 and 2 Boiler Rooms.

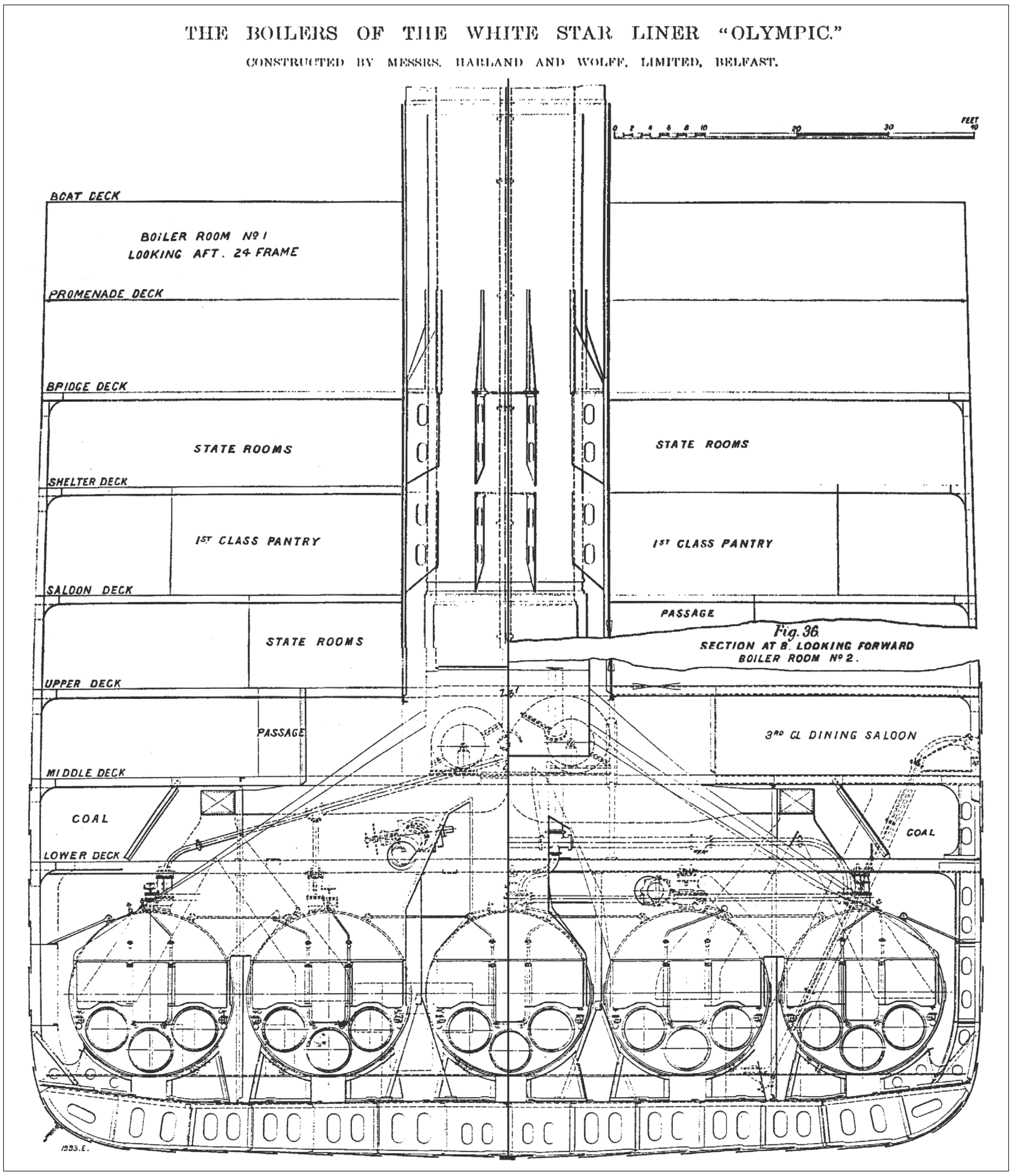

THE BOILERS OF THE WHITE STAR LINER "OLYMPIC."
CONSTRUCTED BY MESSRS. HARLAND AND WOLFF, LIMITED, BELFAST.
0 2 4 6 8 10 20 30 40 FEET
BOAT DECK
BOILER ROOM No 1
LOOKING AFT. 24 FRAME
PROMENADE DECK
BRIDGE DECK
STATE ROOMS
STATE ROOMS
SHELTER DECK
1ST CLASS PANTRY
1ST CLASS PANTRY
SALOON DECK
PASSAGE
Fig. 36.
SECTION AT B. LOOKING FORWARD
BOILER ROOM No 2.
STATE ROOMS
UPPER DECK
PASSAGE
3RD CL DINING SALOON
MIDDLE DECK
COAL
COAL
LOWER DECK
1333.E.

Fig. 15-5 **Boiler Rooms** – Transverse sections through Nos 1 and 2 Boiler Rooms; Boiler Room No.1 is depicted to the left of the centerline, while No.2 is depicted to the right.

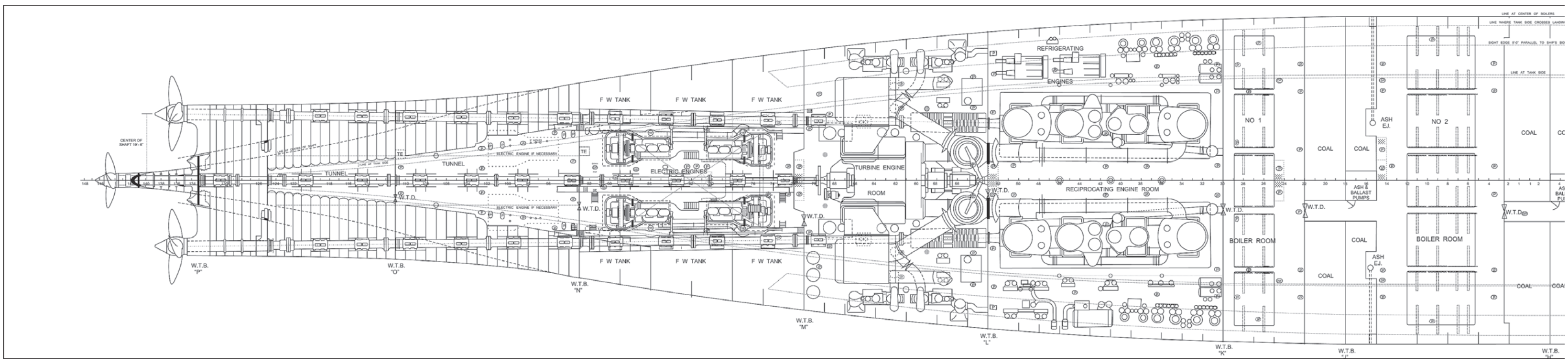
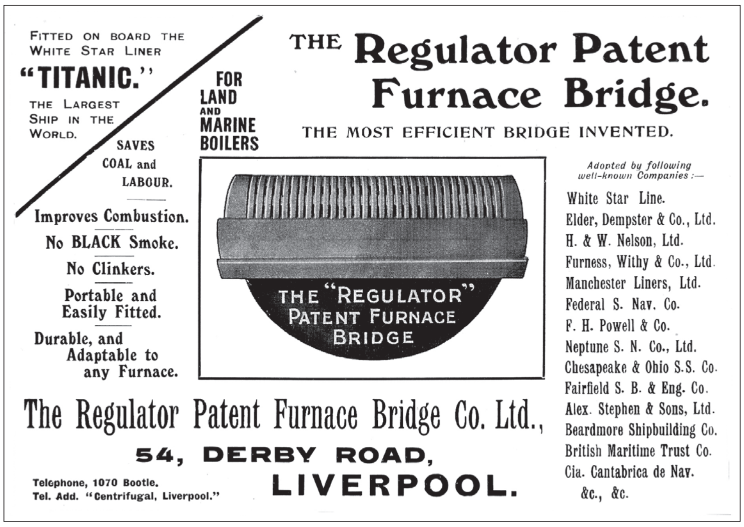

F W TANK
F W TANK
F W TANK
TUNNEL
TUNNEL
ELECTRIC ENGINES
TURBINE ENGINE ROOM
REFRIGERATING ENGINES
RECIPROCATING ENGINE ROOM
W.T.D.
NO 1
NO 2
COAL
ASH E.J.
ASH BALLAST PUMPS
BOILER ROOM
BOILER ROOM
W.T.B. "P"
W.T.B. "O"
W.T.B. "N"
W.T.B. "M"
W.T.B. "L"
W.T.B. "K"
W.T.B.

Fig. 15-8 **Tank Top** – *Titanic*'s Tank Top, showing general arrangements of boilers, engines and auxiliaries. *(Illustration by Bruce Beveridge)*

Right Fig. 15-6 **Advertisement for 'The Regulator Patent Furnace Bridge'** – The 'Regulator' bridge had the addition of a raised, arched grille which promoted better draft at the back of the fire bars, eliminating the clinkers which tended to form in this area due to incomplete combustion. *(*The Shipbuilder*/ Authors' collection)*



FITTED ON BOARD THE WHITE STAR LINER "TITANIC." THE LARGEST SHIP IN THE WORLD.

FOR LAND AND MARINE BOILERS

SAVES COAL and LABOUR.

THE Regulator Patent Furnace Bridge.

THE MOST EFFICIENT BRIDGE INVENTED.

Improves Combustion.
No BLACK Smoke.
No Clinkers.
Portable and Easily Fitted.
Durable, and Adaptable to any Furnace.

THE "REGULATOR" PATENT FURNACE BRIDGE

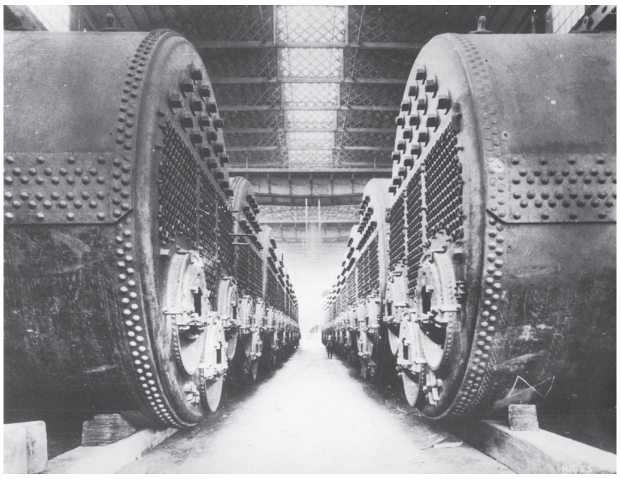
Adopted by following well-known Companies :—

White Star Line.
Elder, Dempster & Co., Ltd.
H. & W. Nelson, Ltd.
Furness, Withy & Co., Ltd.
Manchester Liners, Ltd.
Federal S. Nav. Co.
F. H. Powell & Co.
Neptune S. N. Co., Ltd.
Chesapeake & Ohio S.S. Co.
Fairfield S. B. & Eng. Co.
Alex. Stephen & Sons, Ltd.
Beardmore Shipbuilding Co.
British Maritime Trust Co.
Cia. Cantabrica de Nav.
&c., &c.

The Regulator Patent Furnace Bridge Co. Ltd.,
54, DERBY ROAD,
LIVERPOOL.

Telephone, 1070 Bootle.
Tel. Add. "Centrifugal, Liverpool."

Below Fig. 15-7 **Boilers in the Shop** – The completed boilers of *Olympic* await installation aboard the ship.

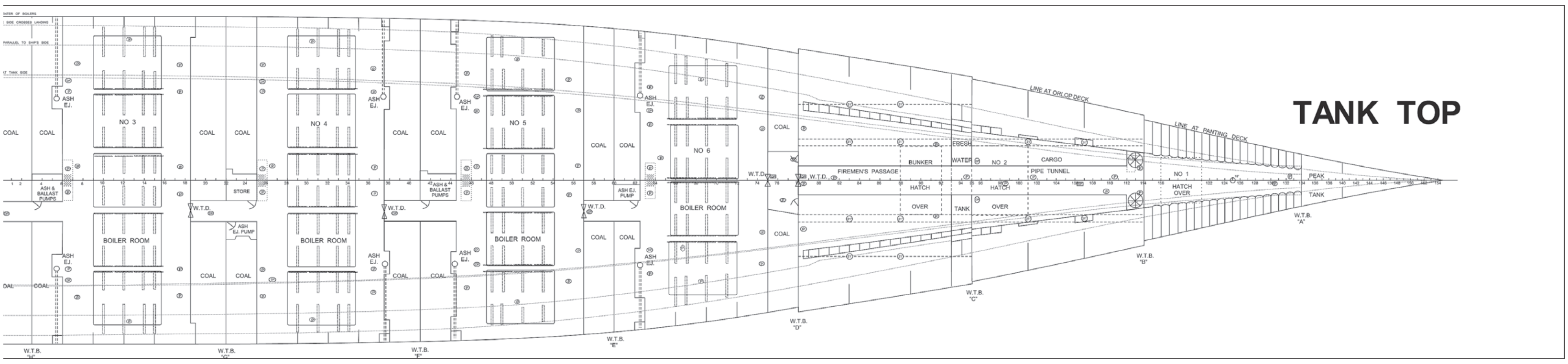


this compartment contained the main condensers and their circulating pumps and air pumps; the evaporators and distilling plant; the forced-lubrication pumps and filters and their two oil coolers and a pump for circulating water through them; and several pumps for bilge and other purposes.

Aft of this, the Electric Engine Room, which contained the four 100-volt-DC main generating sets, extended another 66ft aft to WTB N. The shaft tunnels occupied the remaining portion of the after end of the ship below the Orlop Deck to WTB P, which was the after peak bulkhead. The stern tube for the center screw passed through this bulkhead to the end of the boss in the stern frame casting, just ahead of frame 144A, where the center tailshaft exited the hull.

Boilers

Steam was generated by a plant comprised of twenty-four double-ended and five single-ended boilers, designed for a working pressure of 215lb per square inch gauge (PSIG), maintained under natural-draft conditions. The aftermost, or No.1, Boiler Room contained the five single-ended boilers, while Boiler Room Nos 2, 3, 4 and 5 each contained five double-ended boilers, and the foremost, or No.6, boiler room contained four double-ended boilers. The great breadth of the ship, as well as the absence of longitudinal coal bunkers common in other ships of the time allowed for the arrangement of five boilers abreast, as shown in the general arrangements, except in No.6 Boiler Room



where the increasing fineness of the hull permitted only four boilers to be fitted. The five single-ended boilers in No.1 Boiler Room were arranged for running the auxiliary machinery when in port including the main generator sets, as well as being provided with connections to the main steam supply lines.

Each double-ended boiler was 15ft 9in in diameter, 20ft long, and contained six furnaces. The single-ended boilers were of the same diameter as the double-ended but only 11ft 9in long; each contained three furnaces. This resulted in a total of 159 furnaces. The furnaces were all of the Morrison type, having an inside diameter of 3ft 9in, and were provided with furnace fronts of the Downie 'boltless' pattern. The firebars were of the Campbell type, supplied by the firm of Railton, Campbell & Crawford, of Liverpool.

Within each furnace was an interior partition called a furnace bridge, or 'bridge wall'. This was located at the back end of the fire bars which formed the grate. In addition to supporting the back end of the grate, the lower portion of the furnace bridge separated the lower portion of the furnace tube (the 'ash pit') from the upper portion (the crown, or 'firebox'). The heat and gases of combustion were kept above the grate while all air drawn in through the ash pit by the draft of the fire passed through the burning fuel resting on the grate.

Common to the practice of the day, the shells of the single-ended boilers were formed in one strake, the double-ended boilers having three strakes. Each strake was formed by a rolled upper and lower half, joined together by riveting through double butt straps, the thickness of the inner and outer straps being $1^{5}/_{16}$in in all cases. In the case of the double-ended boilers, the two end strakes were formed as 'out' strakes, overlapping the center, or 'in' strake. All of the boiler shell plates were of mild steel $1^{11}/_{16}$in thick. The boiler end plates were also of mild steel, ¾in thick, joined to the shell with rivets in a double zigzag pattern. Details of the construction of one of the double-ended boilers may be found in Figures 15-9 and 15-10 which illustrates a nearly-identical boiler for *Britannic*, the third ship of the class. (*Britannic*'s double-ended boilers were 12in longer than those of the previous two ships to accommodate longer tubes, which provided an additional 6,816sq.ft of heating surface.) Construction details for the single-ended boilers were generally similar, the main difference being in the previously mentioned number of furnaces and shell strakes, and the manner in which the combustion chambers were stayed. A view of the boilers arranged in the shops is given in Fig. 15-7.

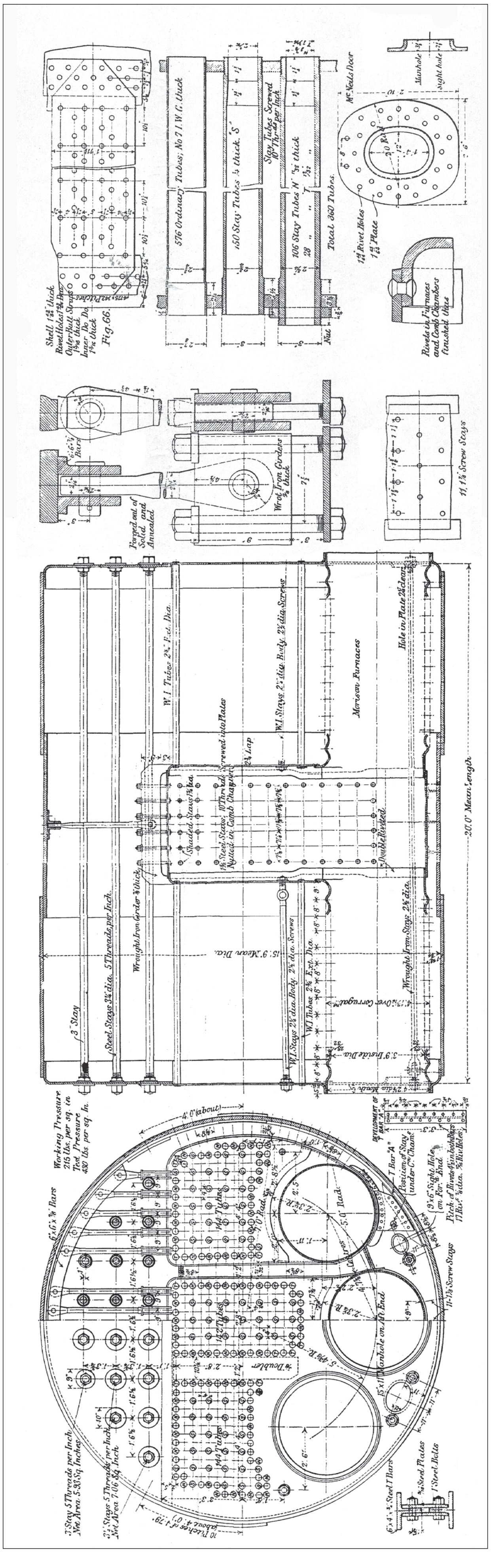
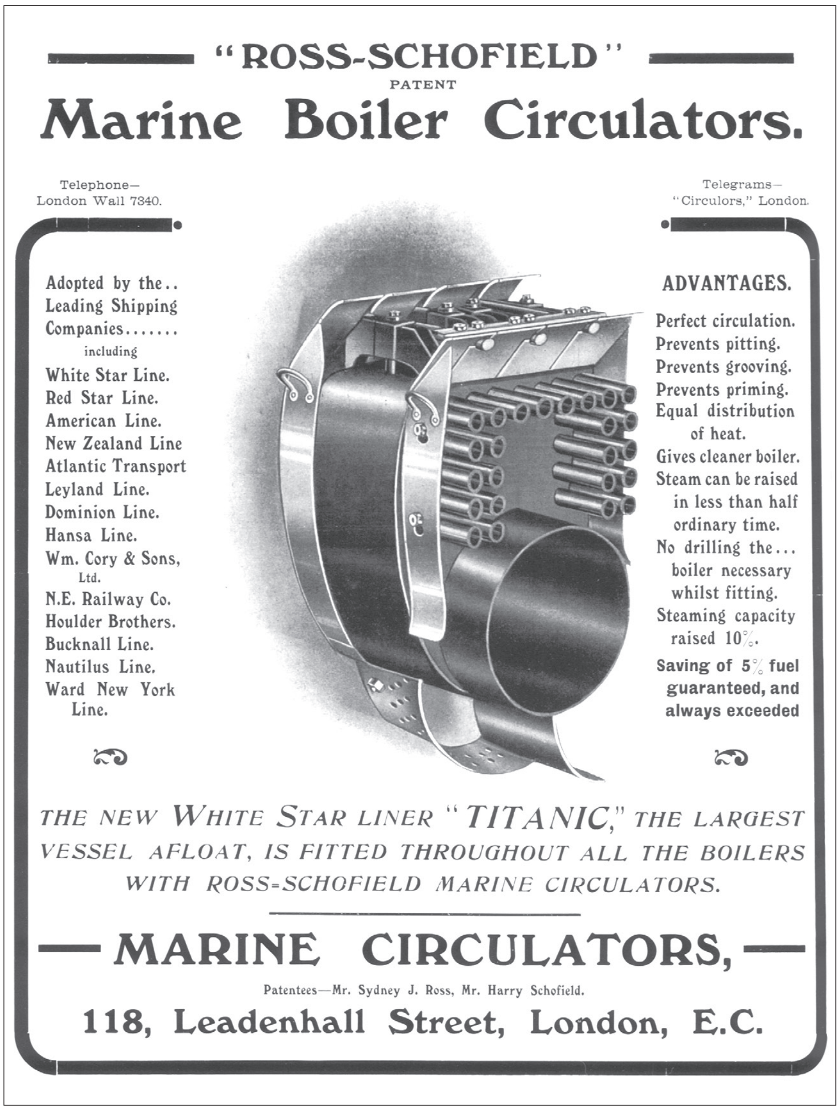


Fig. 15-9 **Double-Ended Scotch Boiler** – End view, longitudinal section and internal details of a double-ended boiler for *Britannic*.



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THE NEW WHITE STAR LINER "TITANIC," THE LARGEST VESSEL AFLOAT, IS FITTED THROUGHOUT ALL THE BOILERS WITH ROSS-SCHOFIELD MARINE CIRCULATORS.

MARINE CIRCULATORS,

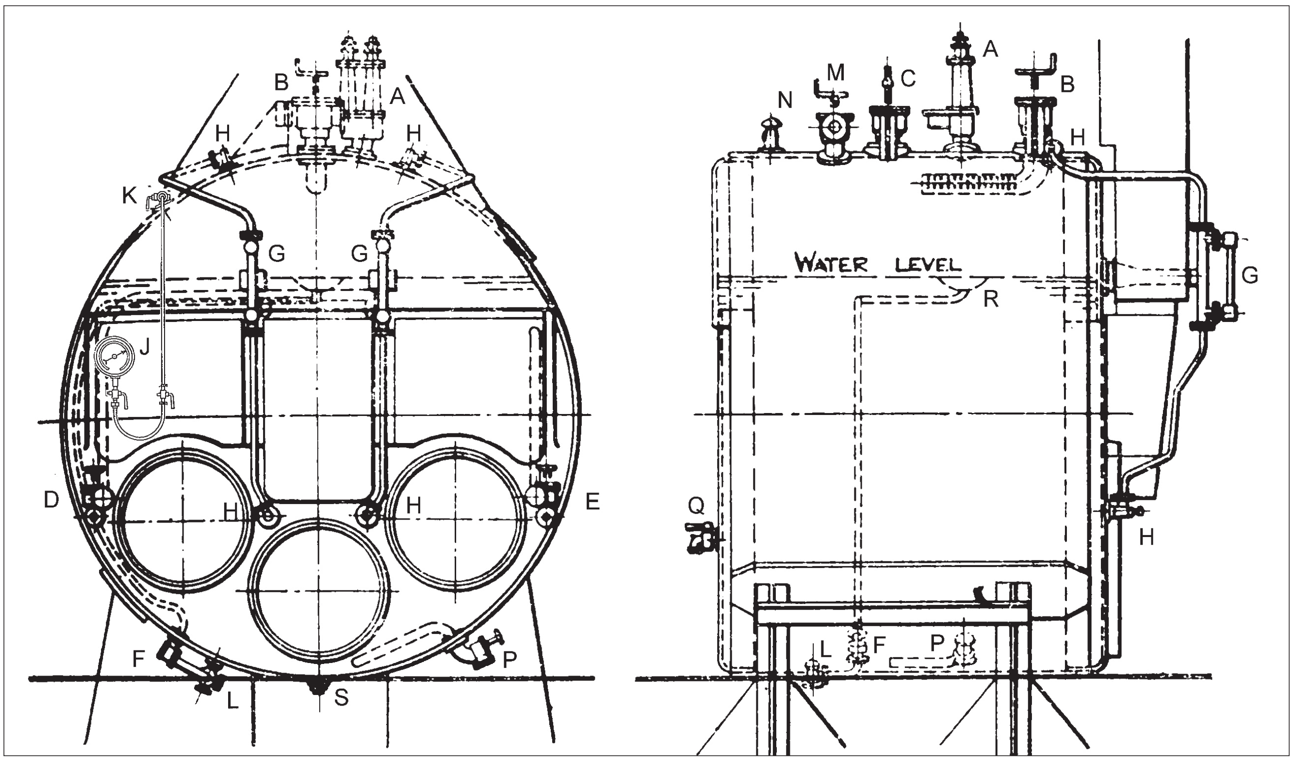
Patentees—Mr. Sydney J. Ross, Mr. Harry Schofield.

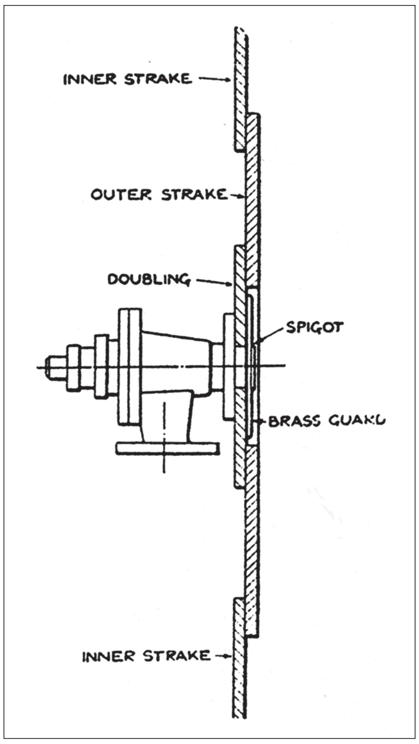
118, Leadenhall Street, London, E.C.

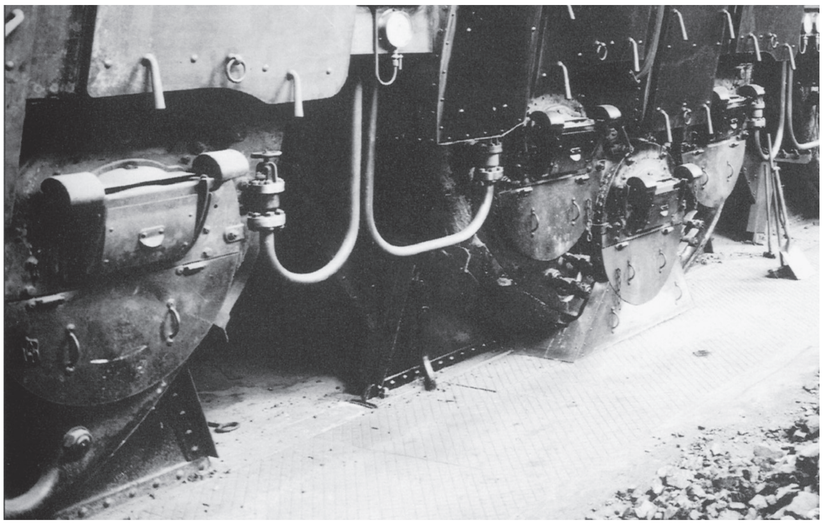
Left Fig. 15-10 **Ross Schofield Advertisement** – The boilers of the *Olympic*-class ships were fitted internally with these baffle plates which promoted proper circulation of the water throughout the boiler by redirect the rising convection currents in a continuous circular motion towards the outer ends, and then back down and rearward beneath the furnaces towards the combustion chambers. *(*The Shipbuilder*/ Authors' collection)*

Below Fig. 15-11 **Boiler Connections – Scotch boiler** – typical connections. *(Scott Andrews collection)*

A – Automatic safety Valves
B – Main Stop Valve
C – Auxiliary Stop Valve (when fitted)
D – Main Feed Non-Return Valve
E – Auxiliary ('Donkey') Feed Non-Return Valve
F – Surface Blow-Off Valve
G – Water Gauges
H – Water Gauge Cocks
J – Pressure Gauge(s)
K – Pressure Gauge Cock(s)
L – Bottom Blow-Off Valve
M – Electric Engine Stop Valve (when fitted)
N – Air Valve (used when draining or filling)
P – Circulating Valve
Q – Salinometer Cock (for obtaining water samples)
R – Scum Pan
S – Drain Plug

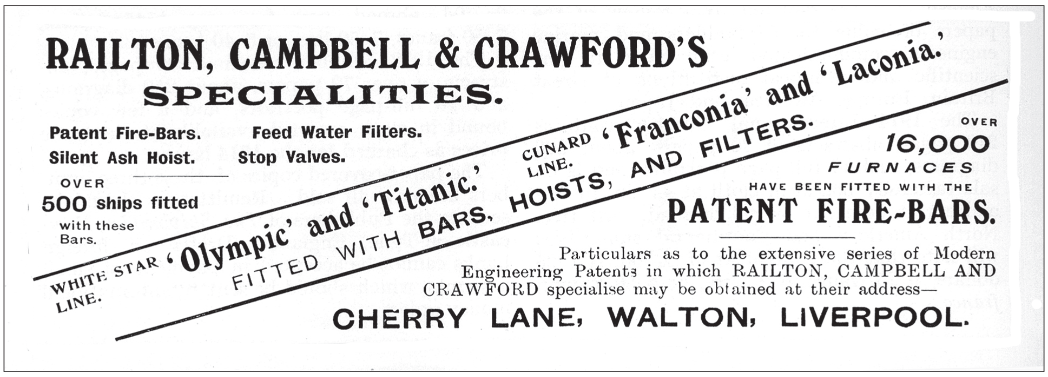






Above Fig. 15-13 **Furnace Fronts** – The marine-type Scotch boilers in Harland & Wolff's shipyard power plant were outfitted with Downie 'boltless' furnace fronts identical to those installed aboard the *Titanic. (*The Engineer/*Authors' collection)*

Left Fig. 15-12 **Boiler Blow-Down Cock** – Typical boiler blow-down cock as fitted in an outer strake. The underflush installation and the brass guard-plate were required to satisfy both the Board of Trade regulations and Lloyd's Rules.



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Particulars as to the extensive series of Modern Engineering Patents in which RAILTON, CAMPBELL AND CRAWFORD specialise may be obtained at their address—

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Fig. 15-14 **Advertisement for Railton, Campbell & Crawford** – The wide variety of fittings and equipment manufactured and supplied by this company were used throughout the machinery and boiler spaces.

Boiler Data

–	Double-Ended	Single-Ended
Number of boilers	24	5
Diameter	15ft 9in	15ft 9in
Length	20ft 0in	11ft 9in
Number of tubes each (total)	860	430
Number of stay tubes each	284	142
Outside diameter of tubes	2¾in	2¾in
Number of furnaces	6	3
Number of furnaces, total	159	
Length of firebars	5ft 9in	
Heating surface, total	144,142sq.ft	
Grate surface, total	3,466sq.ft	
Weight of boiler, each	91½ tons	57⅜ tons
Weight of water in boiler, each[21]	48½ tons	29 tons
Total weight of water in boilers[21]	1,309 tons	
Working boiler pressure (PSIG)	215	215
Test pressure (PSIG)	430	430

Fig. 15-11 shows the internal and external features typical of Scotch boilers. Though the positions of these features varied from one design to another, they were present on all such boilers, including those aboard *Titanic*. These features included:

(A) Automatic safety valves
To relieve pressure when it exceeded the safe limit. Also operable by remote hand lifting gear from the stokehold floor; the exhaust side of each safety valve was connected to a manifold running athwartships from both sides to the centerline, where it joined the bottom end of a steam escape pipe which vented to the atmosphere from pipes led up the forward and after sides of the funnels.

(B) Main stop valves
To admit steam into the main steam pipe(s), and thence to the engines and other machinery while underway.

(C) Auxiliary stop valves
To supply steam to the auxiliary machinery, etc. while in port.

(D) Main feed non-return valves
To admit and control the amount of feed-water from the main feed pumps to the boiler.

(E) Donkey feed non-return valves
To admit and control the amount of feed-water from the auxiliary feed pumps to the boiler; also acted as the feed-water return connections when circulation was being assisted by the donkey pump during start-up or while operating with fires banked.

(F) Surface blow-off
To skim-off the accumulation of greasy matter from the surface of the water within the boiler via the scum pan.

(G) Water gauge(s)
To show the correct level of water in the boiler.

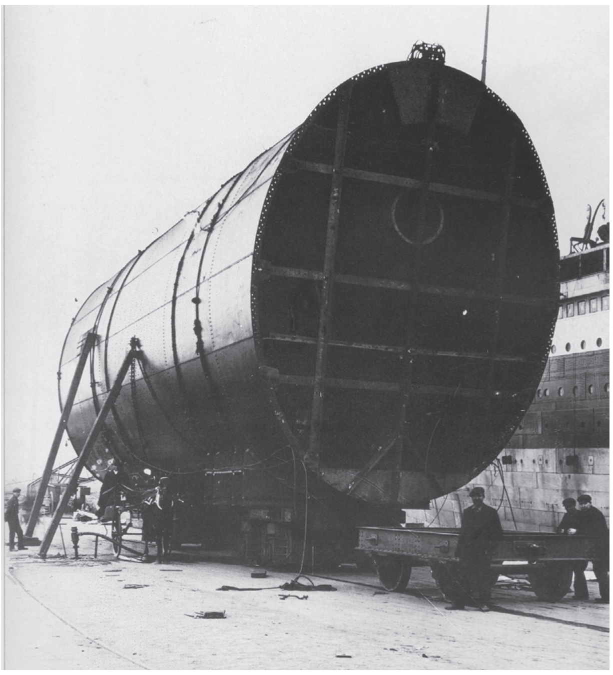

Fig. 15-15 **Funnel Delivered to Fitting-Out Wharf** – One of *Olympic*'s funnels, still strapped to the shipyard tramway wagons, awaiting installation. (The Shipbuilder/*Authors' collection)*

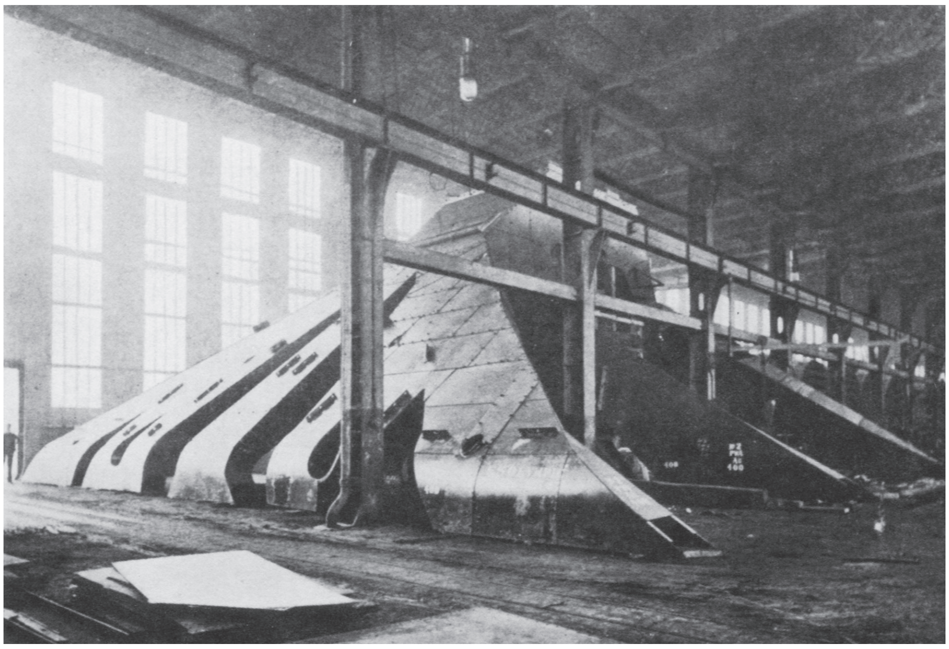

Fig. 15-16 **Boiler Uptakes** – The complete set of boiler uptakes for the Nos 1 and 2 Boiler Rooms being trial-assembled in the shops prior to being dismantled and re-erected aboard the ship. (The Shipbuilder/*Authors' collection)*

(H) Water gauge cocks

To provide a connection to the water gauge(s), and to provide a means of isolating the gauge from the boiler should the glass become broken (each gauge also had its own independent set of cocks to vent off entrapped steam or air, and to blow off clouded water, operable by pull rods from the stokehold floor).

(J) Pressure gauge(s)

To indicate the steam pressure above atmospheric (PSIG) within the boiler.

(K) Pressure gauge cocks

To provide a connection to the pressure gauge, and to provide a means of isolating the gauge from the boiler should the gauge fail and require replacement.

(L) Bottom blow-offs

Used to drain off water to the bilges to reduce density (salinity) if required and as the supply connection to the donkey pump for circulating or draining feed-water when required. This connection was formerly intended to completely blow out the boiler water through a connection in the ship's side. However, by 1912, the practice of completely blowing-out the boilers had largely been discontinued. During a complete blowing-down, as the water level fell below the tops of the tubes and furnaces, it tended to leave behind the coating of grease and scum that normally floats on top. This coating quickly hardened into a scale which was impossible to remove without completely cleaning out the boiler. Such a coating acted as an insulator between the water and heated surfaces, leading to tube failures and the collapse of furnaces from overheating, the most prevalent cause of explosions in fire-tube boilers.

F. J. TREWENT & PROCTOR'S IMPROVED PATENT
SEES ASH EJECTORS
20
SETS FITTED ON THE
"OLYMPIC" AND "TITANIC."
ALSO FITTED TO ALL THE PRINCIPAL STEAMSHIPS OF THE WORLD—MERCANTILE & NAVAL.
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Fig. 15-17 **Advertisement for See's Ash Ejectors**.

Uptakes and funnels

The arrangement of uptakes by which the smoke and waste gases were conveyed to the funnels was very elaborate, with as many as twenty branches being required as in the case of the No.2 Funnel which serviced Boiler Room Nos 3 and 4. Each set of uptakes serviced two adjoining boiler rooms, with the uptake branches being united immediately above the watertight bulkhead separating the two rooms. The bulkhead served as a structural support to the uptakes and funnel above. The set of uptakes connecting Boiler Room Nos 1 and 2 to the No.3 Funnel is shown in Fig. 15-16 illustrating the complexity of these structures. The gases emerging from the boiler tubes were received by the 'smoke box', a structure of steel plates bolted to the ends of each boiler. Each smoke box was fitted with three hinged doors, one for each bundle of tubes corresponding to the furnace below. These doors allowed access to the ends of the tubes for cleaning and repair. Within the uptakes, hinged

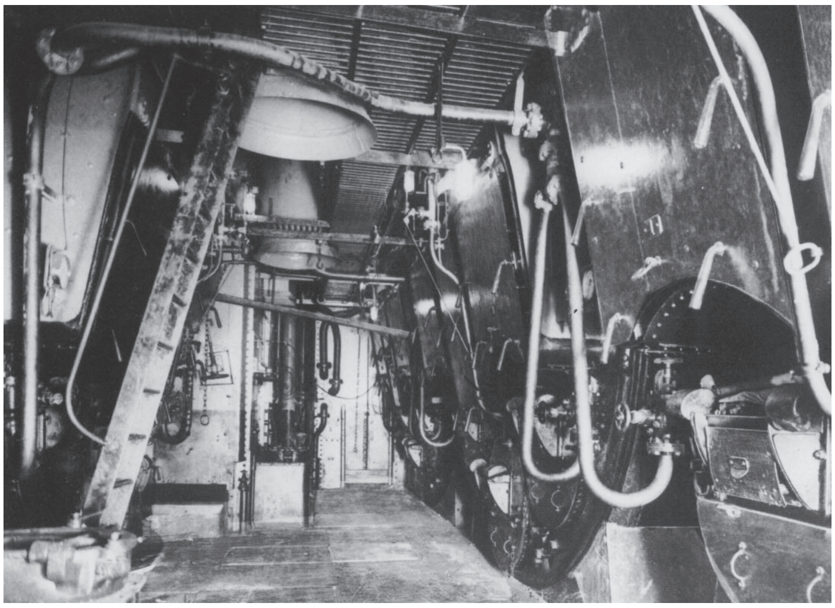


Fig. 15-18 **Stokehold** – A completed firing aisle, or 'stokehold', aboard the Royal Mail Steam Packet Co's *Aragon*, June 1905. Though the layout of this boiler room differs in certain details, this image gives an impression of how one of *Titanic*'s stokeholds would have looked. *(H&W/Authors' collection)*

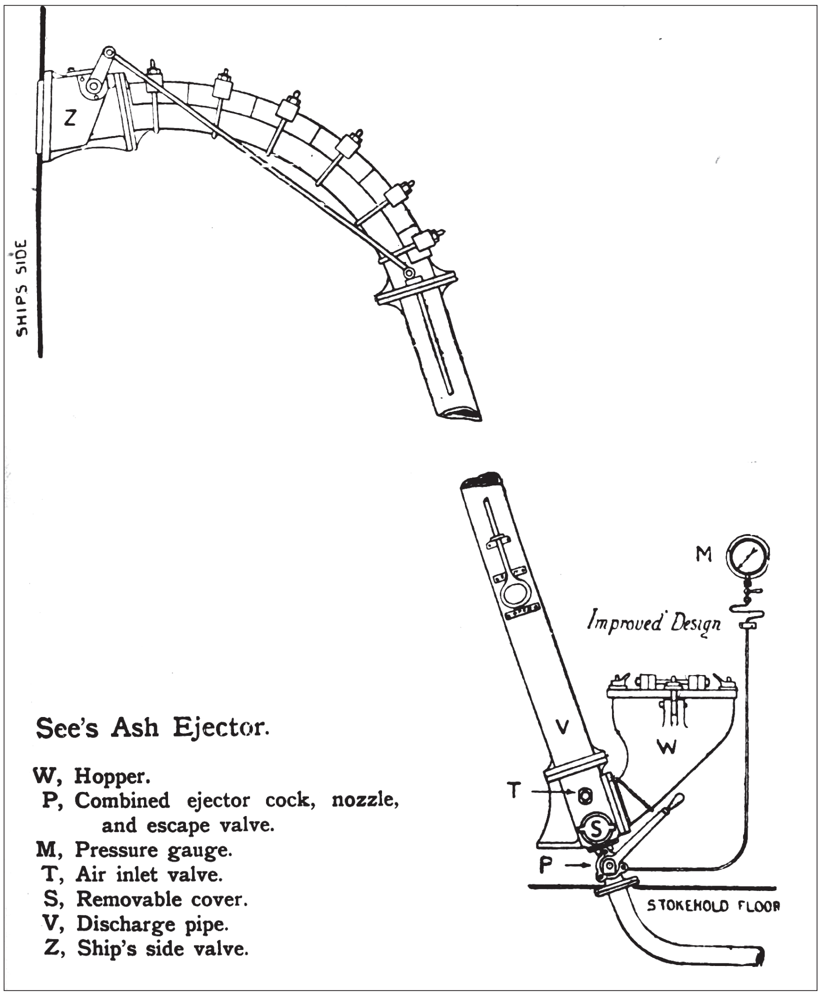
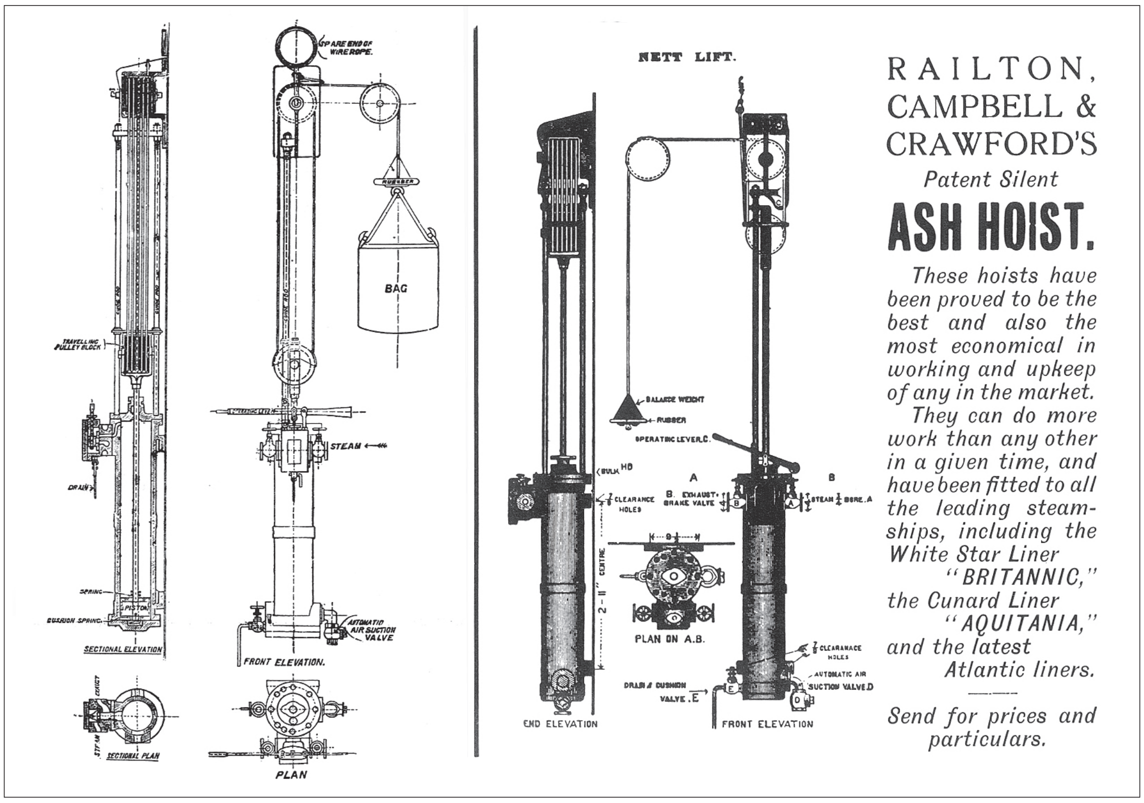

Z
SHIPS SIDE
M
Improved Design
V
W
T
S
P
STOKEHOLD FLOOR
See's Ash Ejector.
W, Hopper.
P, Combined ejector cock, nozzle, and escape valve.
M, Pressure gauge.
T, Air inlet valve.
S, Removable cover.
V, Discharge pipe.
Z, Ship's side valve.

Fig. 15-19 **Ash Ejector** – This diagram shows the main components of a See's ash ejector as installed on *Olympic* and *Titanic*. *(Scott Andrews collection)*


SPARE END OF WIREROPE.
RUBBER
BAG
TRAVELLING PULLEY BLOCK
STEAM
DRAIN
SPRING
PISTON
CUSHION SPRING
SECTIONAL ELEVATION
FRONT ELEVATION.
AUTOMATIC AIR SUCTION VALVE
SECTIONAL PLAN
PLAN
NETT LIFT.
BALANCE WEIGHT
RUBBER
OPERATING LEVER C.
BULK HD
CLEARANCE HOLES
A
B
B EXHAUST & BRAKE VALVE
STEAM ½ BORE A
PLAN ON A.B.
CENTRE
2'-11"
CLEARANCE HOLES
AUTOMATIC AIR SUCTION VALVE D
DRAIN & CUSHION VALVE E
END ELEVATION
FRONT ELEVATION

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These hoists have been proved to be the best and also the most economical in working and upkeep of any in the market. They can do more work than any other in a given time, and have been fitted to all the leading steam-ships, including the White Star Liner "BRITANNIC," the Cunard Liner "AQUITANIA," and the latest Atlantic liners.

Send for prices and particulars.

Fig. 15-20 **Advertisement for Railton, Campbell and Crawford** – In another advertisement from this company, an ash hoist as arranged on *Titanic* is pictured to the left.

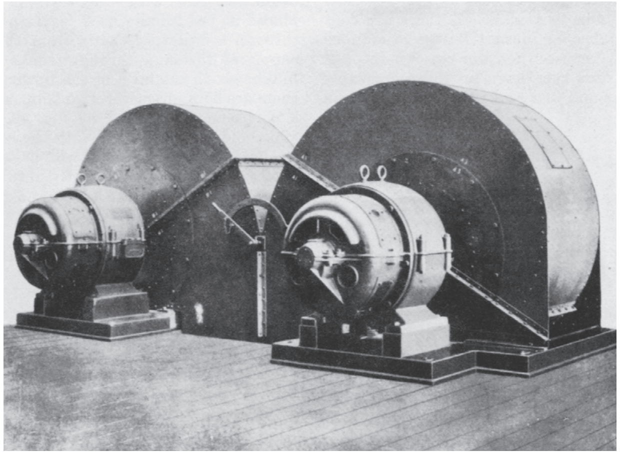


Fig. 15-21 **A Pair of Stokehold Fans**. *(*The Shipbuilder/*Authors' collection)*

dampers were fitted to enable each boiler to be shut off from the uptakes when not in operation, and also while cleaning the fires at the end of each shift. The dampers were operated by pull rods from the stokehold floor. The uptakes were fitted with expansion joints over the boilers in the form of a sleeve with holes for sliding bolts.

The four funnels each had an exterior elliptical cross-section and measured 24ft 6in x 19ft. The dimensions of the flue internal to each funnel varied according to the required cross-sectional area necessary to provide optimum draft for the number of furnaces to which it was connected. The average height of the tops of the funnels above the level of the furnace bars was 150ft. Of the four funnels, the foremost three were required for the removal of combustion by-products from the boiler rooms. The aftermost funnel was a dummy and was used for ventilating purposes and also had built into it the chimney from the extensive galleys as well as the flue from the fireplace in the First Class Smoke Room. A striking photograph of *Olympic*'s No.4 Funnel is reproduced in Fig. 15-15. Further details regarding the structure and outward appearance of the funnels are provided in Chapter 13 of this volume.

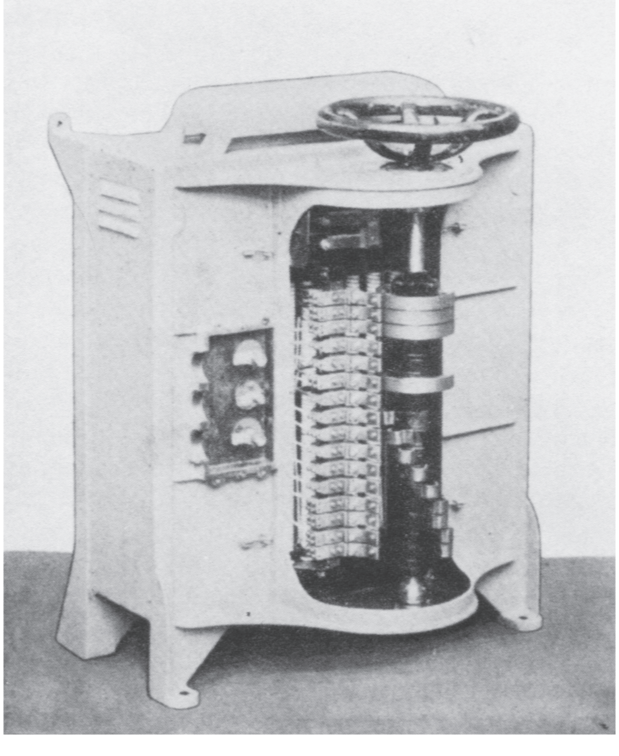


Fig. 15-22 **Stokehold Fan Controller with Cover Removed**. *(*The Shipbuilder/*Authors' collection)*

Bunker arrangements

The arrangements incorporated in *Titanic* for the loading, stowing and handling of coal were the result of many years of operational and design experience on the part of both builder and owner. The upper portions of the bunkers consisted of 'tween deck space on each side of the ship between the Middle (F) and Lower (G) decks. Coal was first shipped into these spaces through coal chutes accessed from the bunker doors located along the hull at the Middle Deck level. From there, the coal was distributed by wheelbarrows and shovels into cross-bunkers which extended the full width of the vessel in each boiler room. Rectangular openings with counterbalanced vertically-sliding doors were let into the cross-bunker end bulkheads at the stokehold level immediately opposite each trio of furnaces. From these doors, the trimmers working as coal passers loaded wheelbarrows of coal, which they then deposited within easy reach of the firemen tending the furnaces. This arrangement reduced the amount of handling of the fuel for each boiler to a minimum. A further advantage of this bunker arrangement was that no watertight doors were required in the bunker ends. Each set of boilers had the necessary coal supply provided within the same watertight compartment, due to the watertight bulkheads dividing the boiler rooms being placed at the center of the cross bunkers. Total capacity within the bunkers surrounding the boiler rooms was 6,611 tons. A further supply of 1,092 tons could be stowed in the No.3 Hold, just forward of No.6 Boiler Room. Access into this compartment from the boiler rooms was gained through two manually operated, vertically hinged watertight doors in the forward bulkhead within the vestibule between the Firemen's Passage and the door through the watertight bulkhead into No.6 Boiler Room.

The coal bunkers and their arrangement and structural details, as well as the manner in which the coal was shipped and handled within the bunkers and boiler rooms, are all described in detail elsewhere in this book.

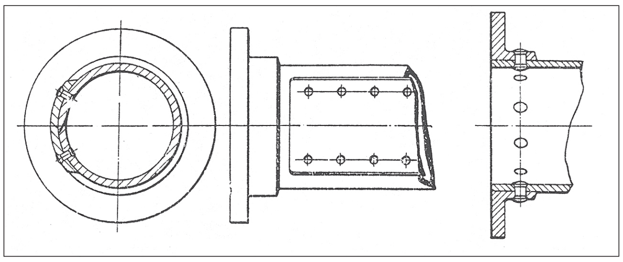


Fig. 15-23 **Section Through a Main Steam Line**.

Ash hoists and ejectors

The arrangements for discharging ashes on the *Olympic*-class liners consisted of ten See's ash ejectors, of which there were two in each of Boiler Room Nos 2 through 6, placed as shown in the General Arrangements. A large duplex feed pump, placed in a separate room adjoining each boiler room, worked the ash ejectors. These pumps will be more fully described later in this chapter. One of the See's ash ejectors is shown on the right-hand section of Fig. 15-5, while Fig. 15-19 shows the basic features of this type of ash ejector. The ashes were discharged by shoveling them into the hopper placed on the stokehold floor. From the hopper, the ashes were drawn down by the rush of air to a water jet which was being discharged through the long inclined pipe shown, at a pressure of about 150lb, the jet being maintained by the pump already referred to. The water jet carried the ashes up the inclined pipe until, at the upper bend, they were deflected and discharged well clear of the ship's side. For use when the vessel was in port, where the deposit of ashes into the water was prohibited, there were four ash hoists supplied by Railton, Campbell & Crawford. Ash hoists of this type were remarkably free from wear and tear and required only a very small supply of steam, a quarter-inch pipe being used for the steam inlet. Fig. 15-20 shows the arrangement and method of working of one of these hoists. The ashes hauled up by the hoists were deposited into a barge moored along side the ship.

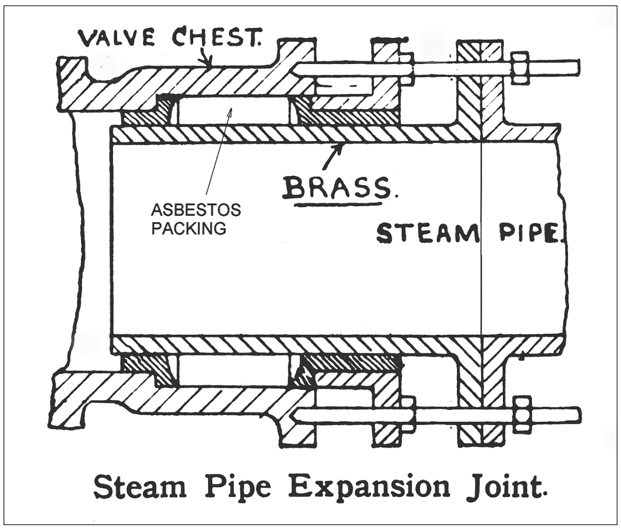


Fig. 15-24 **Steam Pipe Expansion Joint**. *(Scott Andrews' collection)*

Boiler room fans and ventilation

As on all previous ships built for the White Star Line, no forced draft to the boilers was provided, as it was the owner's practice to have forced ventilation only to the boiler rooms of their ships. To provide the large quantity of air required, twelve fans – two for each boiler room – were fitted. The fans were supplied by Davidson & Co., of Belfast, and were of their 'Sirocco' type. The fans were placed in fan rooms at the Middle Deck (F) level and drew in air through ventilating shafts from the Boat Deck. The pair of fans supplying No.1 Boiler Room were of 40in-diameter, while the pair supplying No.6 Boiler Room were of 50in-diameter. The fans for the remaining four boiler rooms were all of 55in-diameter. They were driven by Allen DC electric motors, the horsepower rating of these being 15, 25 and 30 respectively for the aforementioned fan sizes. A pair of these fans is illustrated in Fig. 15-21.

The air from the fans was supplied to the boiler rooms through trunks leading to the firing aisles, discharging at a level just above the furnaces, an outlet having been supplied over each bank of furnaces. The amount of air supplied by the fans was well beyond what was required to provide adequate draft for the fires under all conditions. This abundant supply of air being discharged into the boiler rooms rather than directly to the furnaces realized a secondary benefit in that the stokeholds were somewhat cooler and certainly much better ventilated than was the case in ships employing forced draft directly to the furnaces. Further, as the over-supply was forced up and out through the fidleys located fore and aft of each boiler casing, a great deal of heat was removed from these spaces which would have otherwise been transferred through to the accommodations abutting the casings.

Changing the speed of the fans regulated the amount of air supplied to the boiler rooms. To this end, a controller was supplied for each motor and located within the fan room with the motor to which it was linked. These controllers varied the voltage supplied to the fan motors by engaging and disengaging a series of resistance elements through contacts actuated by a set of cams on a roller drum. The fan controllers could be operated locally from within the fan rooms or remotely from the stokehold floor by rods supported on ball bearings. These bearings were found to have reduced the amount of friction so greatly that the operator

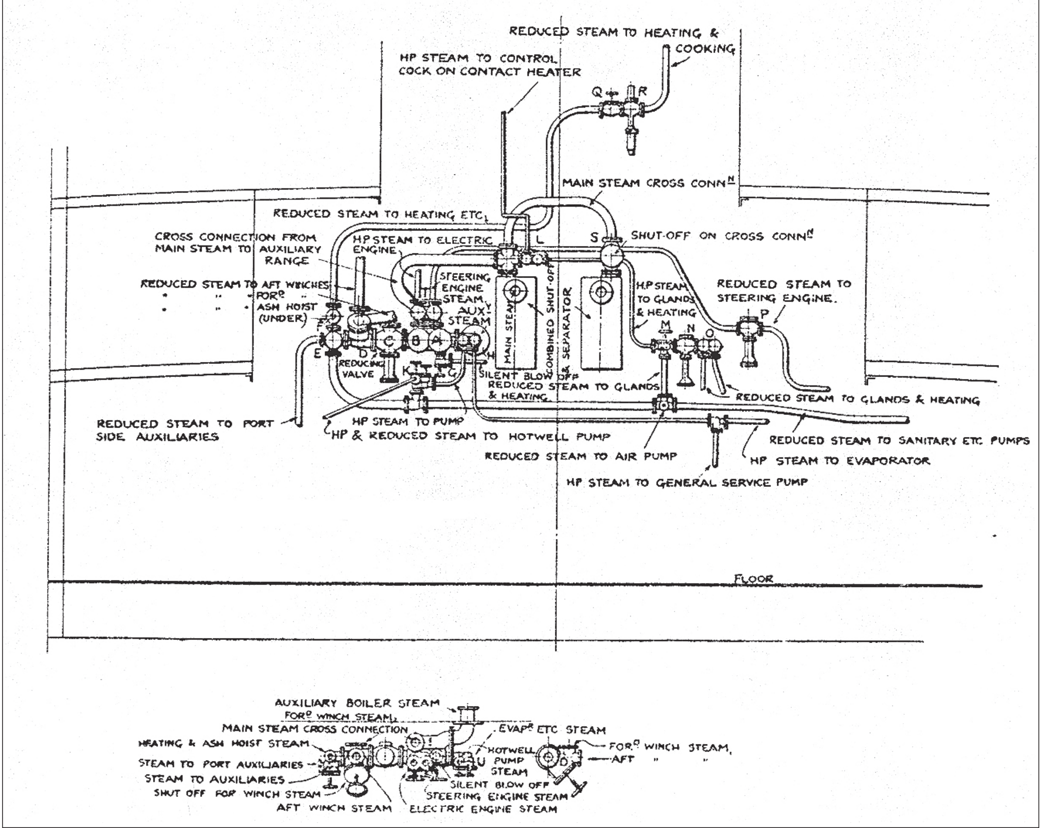

REDUCED STEAM TO HEATING & COOKING
HP STEAM TO CONTROL COCK ON CONTACT HEATER
Q
R
MAIN STEAM CROSS CONNN
REDUCED STEAM TO HEATING ETC.
CROSS CONNECTION FROM MAIN STEAM TO AUXILIARY RANGE
HP STEAM TO ELECTRIC ENGINE
L
S
SHUT-OFF ON CROSS CONNN
REDUCED STEAM TO AFT WINCHES
" " FORD "
" " ASH HOIST (UNDER)
STEERING ENGINE STEAM
AUXY STEAM
MAIN STEAM
COMBINED SHUT-OFF & SEPARATOR
HP STEAM TO GLANDS & HEATING
REDUCED STEAM TO STEERING ENGINE.
P
M
N
O
E
D
C
B
A
H
K
G
REDUCING VALVE
SILENT BLOW OFF
REDUCED STEAM TO GLANDS & HEATING
REDUCED STEAM TO GLANDS & HEATING
REDUCED STEAM TO PORT SIDE AUXILIARIES
HP STEAM TO PUMP
HP & REDUCED STEAM TO HOTWELL PUMP
REDUCED STEAM TO AIR PUMP
REDUCED STEAM TO SANITARY ETC PUMPS
HP STEAM TO EVAPORATOR
HP STEAM TO GENERAL SERVICE PUMP
FLOOR
AUXILIARY BOILER STEAM
FORD WINCH STEAM
MAIN STEAM CROSS CONNECTION
HEATING & ASH HOIST STEAM
STEAM TO PORT AUXILIARIES
STEAM TO AUXILIARIES
SHUT OFF FOR WINCH STEAM
AFT WINCH STEAM
EVAPR ETC STEAM
HOTWELL PUMP STEAM
U
SILENT BLOW OFF
STEERING ENGINE STEAM
ELECTRIC ENGINE STEAM
FORD WINCH STEAM
AFT " "

Fig. 15-25 **Connections on Engine Room Forward Bulkhead to Main and Auxiliary Steam Ranges** – This illustration shows an example of the typical connections found on a twin-screw steamer built by H&W in the first decades of the twentieth century. Similar, but more numerous and diverse, connections could be found on the *Olympic*-class liners.

below could easily feel each individual position on the controller. One of the stokehold fan controllers with the cover removed is shown in Fig. 15-22.

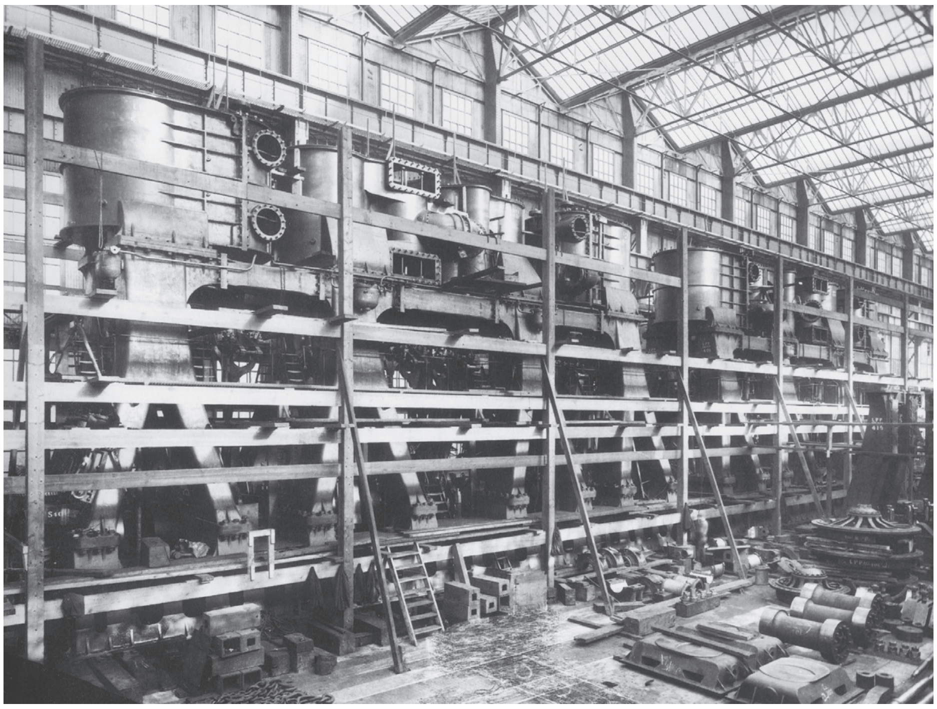
Steam pipes and valves

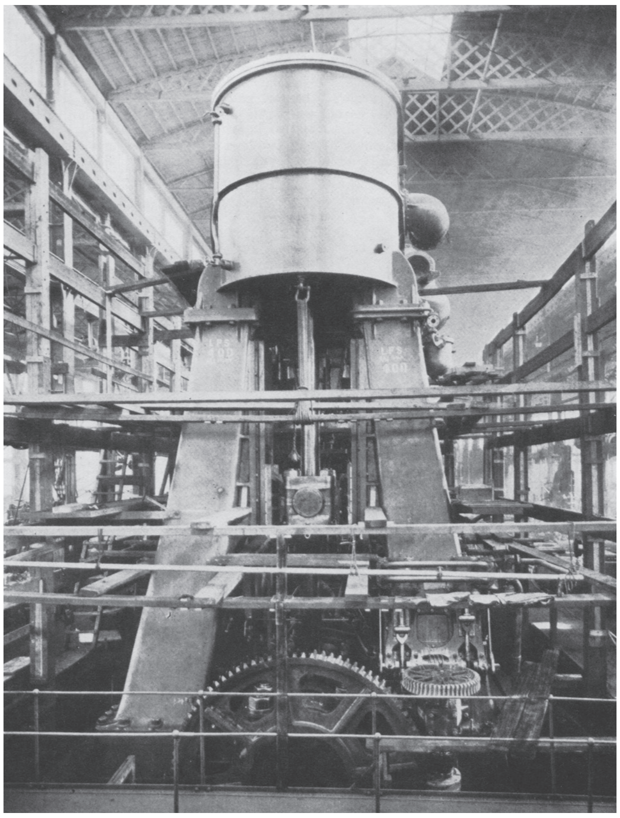
The steam supply was carried from the boilers to the reciprocating engines by two main steam pipes formed from rolled steel, the seams then being machine electric-arc welded. A butt strap was then riveted over the weld. Per the requirements of the Board of Trade, a butt strap was required over the entire length of the weld in addition to the electric lap-welding. Electric and gas welding – relatively new technologies in the early twentieth century – were still looked upon with some suspicion. The flanges on these pipes were secured by a single row of rivets as indicated in the section through the flange.

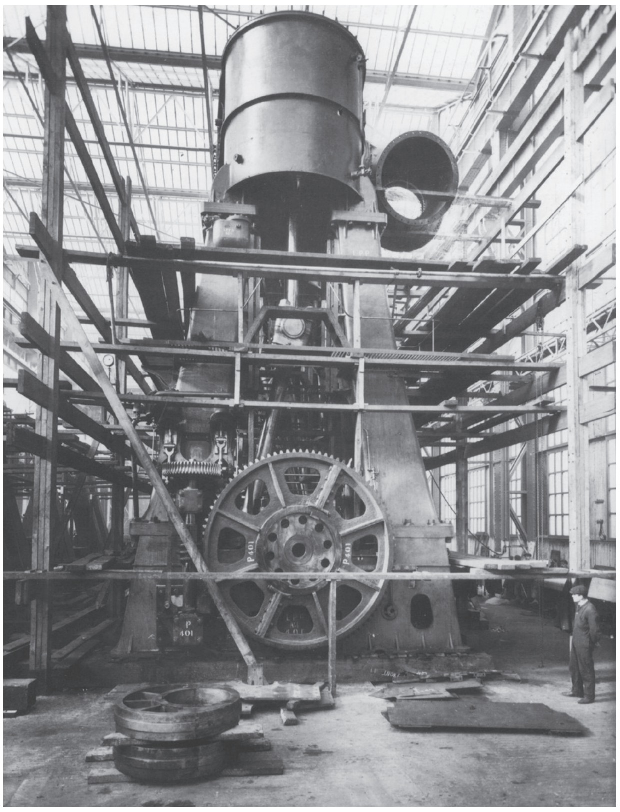
Branch lines were carried out from the various boilers to these pipes. Each main steam line gradually increased in diameter as it approached the forward bulkhead of the Reciprocating Engine Room. The main steam lines were fitted through specially-constructed tunnels which provided unimpeded passage through the coal bunkers up to the watertight bulkhead separating each boiler room. At each watertight bulkhead, the steam lines passed through a watertight flange. Expansion of the lines due to heating was taken up by expansion couplings fitted on the fore and aft sides of the T-fitting connecting the main lines to the branch lines from the boilers. A coupling of similar design is shown in Fig. 15-24.

On the forward side of the bulkhead separating the Reciprocating Engine Room and No.1 Boiler Room, on each main pipeline, was a Cockburn quick-acting balanced emergency stop valve, which could be closed in a few seconds in case of rupture of the line. Cross connections were fitted between the mains in each boiler room, with stop valves so arranged that any section of the main, with the boilers connected to it, could be cut out. This allowed for shutting down

Right Fig. 15-26 **Reciprocating Engines in Shop** – This illustration shows both of *Titanic*'s reciprocating engines in the course of erection in the Engine Works. Here, the engines are situated front-to-front, outboard sides facing the camera, starboard engine to the left and port engine to the right. In the foreground, the shop floor is covered with parts awaiting assembly, stenciled with both the number '401' and an abbreviated indication of the specific location where they belong. At the far right, progress on another smaller set of engines is visible, those for yard No.415, R.M.S.P. Co.'s SS *Arlanza*. *(H&W/ Authors' collection)*

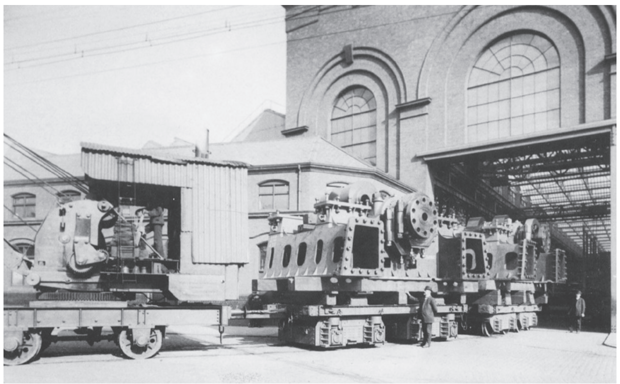




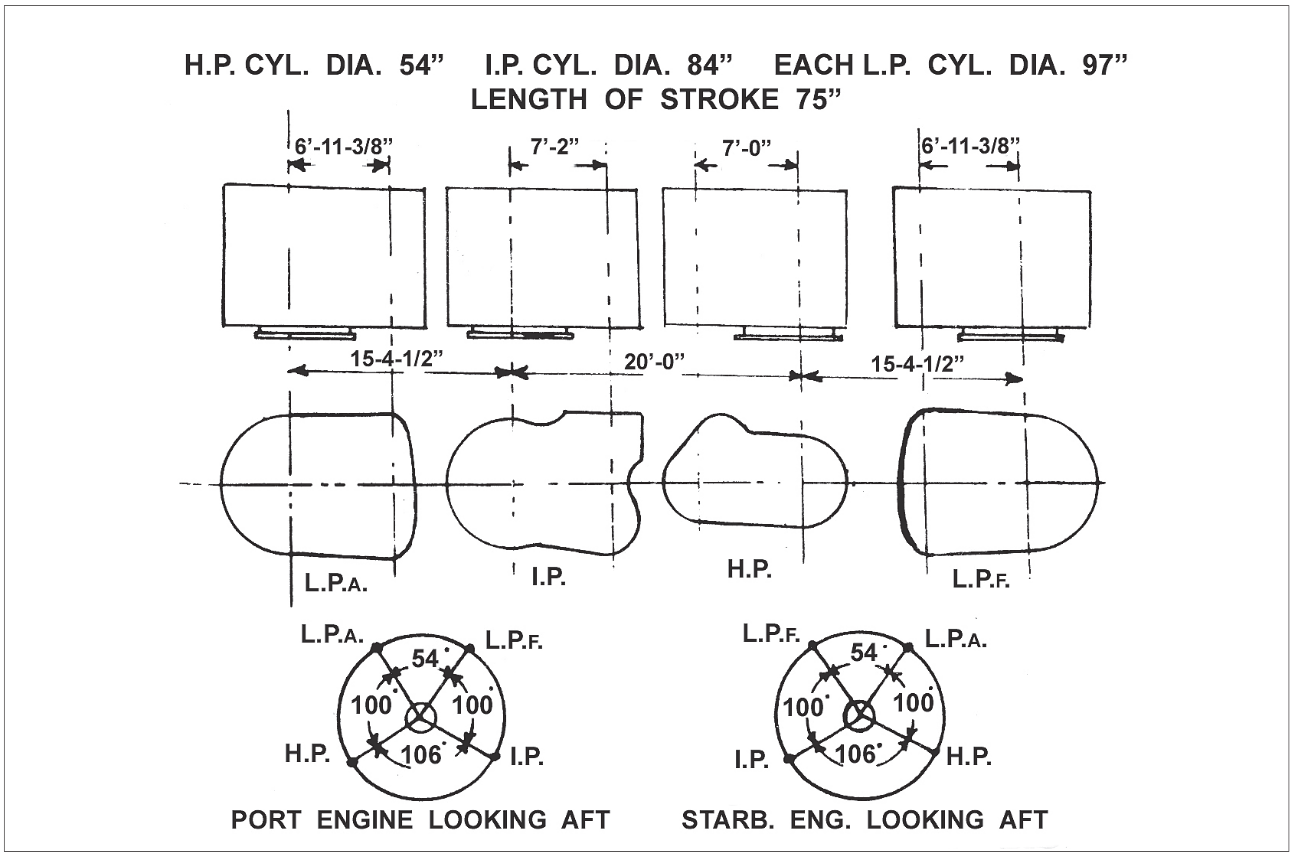


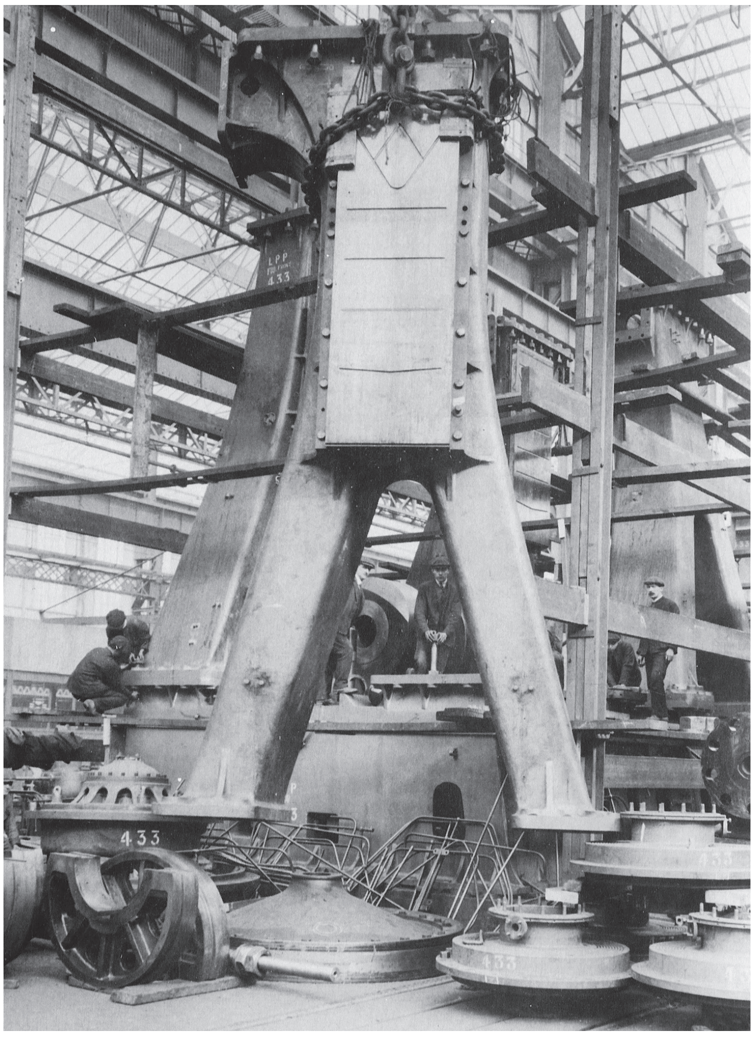
Above Fig. 15-27 **After End of Starboard Engine** – The after end of the *Olympic*'s starboard engine in the Erecting Shop. *(*Engineering*/Authors' collection)*

Above, right Fig. 15-28 **After End of Port Engine** – The after end of the *Titanic*'s port engine in the Erecting Shop.



Right Fig. 15-29 **Engine Bedplates** – Bedplate and crank sub-assemblies being transported to *Britannic* from the shops. *(H&W/ Authors' collection)*


H.P. CYL. DIA. 54" I.P. CYL. DIA. 84" EACH L.P. CYL. DIA. 97"
LENGTH OF STROKE 75"
6'-11-3/8"
7'-2"
7'-0"
6'-11-3/8"
15-4-1/2"
20'-0"
15-4-1/2"
L.P.A.
I.P.
H.P.
L.P.F.
L.P.A.
L.P.F.
54°
100°
100°
106°
H.P.
I.P.
L.P.F.
L.P.A.
54°
100°
100°
106°
I.P.
H.P.
PORT ENGINE LOOKING AFT
STARB. ENG. LOOKING AFT



Above Fig. 15-30 **Cylinder Order and Crank Sequence** – Arrangement of cylinders and angle and rotational sequence of cranks.

Fig. 15-31 **Cylinder Support Column** – Outboard support column belonging to the forward LP cylinder of *Britannic*'s port engine. Here, after trial fitting and assembly, the engines are being partially dismantled for transport to the Fitting-Out Wharf. *(H&W/ Authors' collection)*

any of the boilers without affecting the remainder of the steam supply to the main. Additionally, portions of each main steam line could be isolated from the remainder by shut-off valves fitted into each line at three of the watertight bulkheads. On the after side of the Reciprocating Engine Room bulkhead were the main bulkhead stop valves, 24in in diameter. Each of these valves was provided with a large separator which was automatically drained by steam traps. A cross-connection was provided at this stage as well, which allowed either range of piping to be used for either or both engines.

Lastly, located at the inboard side of the high pressure valve chest of each reciprocating engine were the main stop valves, which were operated by hand wheels and screws from the Starting and Maneuvering Platform situated in the center of the Reciprocating Engine Room at deck level.

A separate range of piping was fitted to supply steam for working the engines of the main generating sets, and to supply steam to the ship's auxiliary machinery. This range was connected to the five single-ended boilers in Boiler Room No.1 as well as to two boilers each in Boiler Room Nos 2 and 4. Further redundancy was added in the form of a cross-connection between the main and auxiliary pipes in the Reciprocating Engine Room so that the auxiliaries could be worked from any boiler in the ship. Steam pipes also were led separately from Boiler Room Nos 2, 3 and 5 above the watertight bulkheads and overhead along the working passage on the Upper Deck (E) to the emergency electric generating sets, located well above the load waterline on Saloon Deck (D) in the Turbine Engine Room casing. Pipes were also led from this steam supply to the pumps which were connected to the bilges throughout the ship.

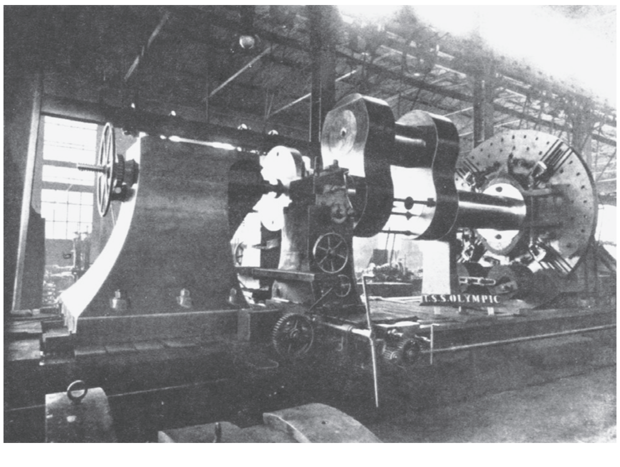


Fig. 15-32 **Crankshaft in Lathe** – A segment of one of *Olympic*'s crankshafts in the lathe. (Engineering/*Authors' collection*)

Reciprocating engines

The two sets of reciprocating engines were of the four-cylinder, triple-expansion, direct-acting inverted type, balanced on the Yarrow, Schlick and Tweedy system. After a slight drop in pressure due to expansion within the

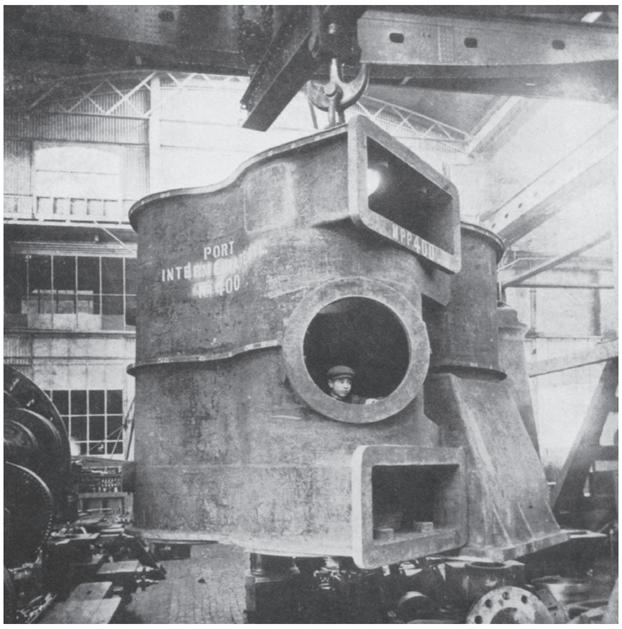


Fig. 15-33 **Port Intermediate Cylinder Casing** – The completed casting prior to machining. (The Shipbuilder/ *Authors' collection*)

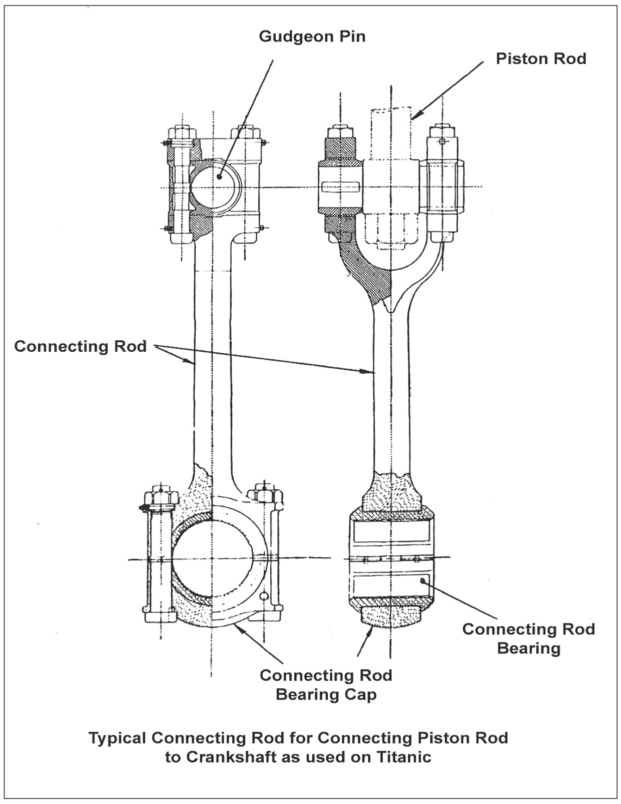
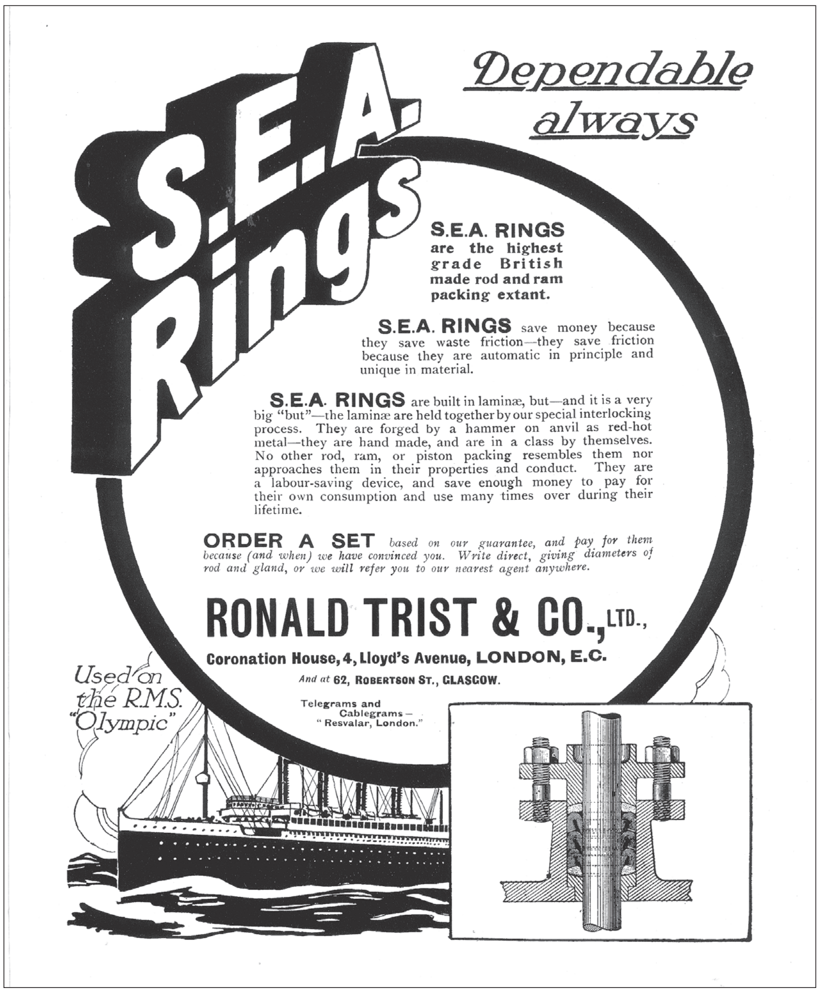

Gudgeon Pin
Piston Rod
Connecting Rod
Connecting Rod Bearing
Connecting Rod Bearing Cap
Typical Connecting Rod for Connecting Piston Rod to Crankshaft as used on Titanic

Fig. 15-34 **Connecting Rod** – This illustration shows the principal components of a connecting rod assembly. *(Scott Andrews collection)*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And at **62, ROBERTSON ST., GLASGOW.**

Telegrams and
Cablegrams—
"Resvalar, London."

Fig. 15-35 **Advertisement for Ronald Trist and Co S.E.A. Rings** – An advertisement for the suppliers of the packings used in the piston rod glands of the main engines and auxiliary machinery. *(*The Shipbuilder*/Authors' collection)*

various supply lines and valves, steam from the boilers arrived at the high-pressure cylinder of each engine at 210PSIG. Steam exhausted from the high-pressure cylinder was then directed to the intermediate-pressure cylinder, where it was received at a pressure of 78PSIG. After doing its work in the intermediate-pressure cylinders, the steam was then exhausted to the respective low-pressure cylinders, where it was received at 24PSIG for further expansion. After having been expanded as far as practical within the reciprocating engines' low-pressure cylinders, the steam was exhausted at a pressure of about 9lb per square inch absolute (PSIA) – below atmospheric pressure – and directed towards either the low pressure turbine or directly to the condensers.

The two low-pressure cylinders were placed one at each end of each set of engines, as was usual with the balancing system adopted. The order of the cylinders, beginning from forward, was low-pressure, high-pressure, intermediate-pressure and low-pressure. For each set of engines, the cylinder diameters were as follows: high-pressure cylinder, 54in; intermediate-pressure cylinder, 84in; and low-pressure cylinders, 97in each. The stroke in all cases was 75in. Each set of engines was designed to indicate about 15,000 HP at 75 revolutions per minute, though in service the designed output was exceeded by a fairly comfortable margin.

In general design and construction, these engines followed the long-tried practice of Harland & Wolff. Plan, elevation and sectional views of the Reciprocating Engine Room are given in Figs. 15-1, 15-2 and 15-3. A view of both sets of engines in the course of erection in the shops is given in Fig. 15-26 and a view of the after end of the port engine is given in Fig. 15-28 Some appreciation of the great size of these engines may be gained by the fact that each set was approximately 63ft in length and weighed 720 tons.

Each set of engines was built upon a bedplate built up in five sections from massive iron castings which were then bolted together, weighing 195 tons complete. The individual sections of the bedplates were comprised of two fore-and-aft box girders cast integral with athwartship girders which supported the main crankshaft bearings. This arrangement simplified construction as well as final alignment and machining of the bedplate, in addition to providing a more rigid foundation that had fewer tendencies to flex in sympathy with engine vibrations. Each of the four larger segments contained the necessary seats for the two sets of crankshaft bearings required to support each crankshaft segment beneath the corresponding cylinder.

The crankshaft for each set of engines was constructed in four sections, coupled together at corresponding flanges with high-tension steel bolts. Each of the sections was fabricated in the 'built-up' manner, with the crank webs and coupling flanges being shrunk on and pinned to the shafts and crank pins; the material throughout was forged steel. These crankshafts were of massive construction. The crank pins in all cases were 27¾in in diameter, the length in the case of the high- and intermediate-pressure cylinders being 35in, and in the low-pressure cylinders 24½in. The crank shafts were all 27in in diameter with a 9in hole bored through the center. The weight of each crankshaft complete was 118 tons. Each crankshaft was supported in eight bearings, two being provided per crank pin. These bearings had cast-steel bushes lined with white metal. Cast steel keeps, held in place by heavy studs passed through the bedplate, secured the shaft and bearings. Heavy nuts were fitted at each end of the studs, as well as lock pins to prevent the nuts from slackening back. There was water service through the keeps for cooling purposes and, in addition to oil service at the top, there were pipes through the flanges at the ends of the bottom bushes. The oil service to these bearings was by gravity.

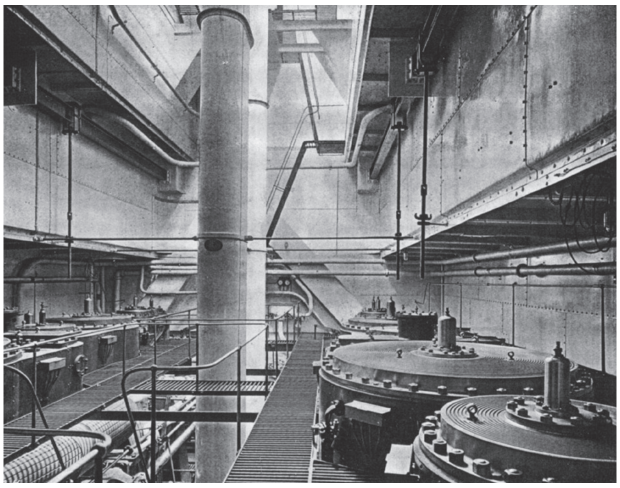


Fig. 15-36 **Engine Room Upper Platform, SS *Avon*** – This photo of the platform at the level of the cylinder covers aboard the R.M.S.P. Co.'s SS *Avon* (1907) gives a good general impression of how the upper levels of *Titanic*'s Reciprocating Engine Room appeared. Note the builder's plaque on the ventilation trunking – typically, the builder of the machinery – even when it was the shipbuilder themselves – always installed a plaque in the machinery spaces; the plaque on *Titanic*'s forward deckhouse at B Deck wasn't the only one fitted aboard the ship. *(*Engineering*/Scott Andrews collection)*

As stated above, the reciprocating engines were balanced on the Yarrow, Schlick and Tweedy system. In order for this system of engine balancing to be adopted, the engine to which it was applied had to have at least four cranks. This, along with the reduction in weight in the individual moving parts achieved when dividing the low-pressure expansion stage between two smaller cylinders, was the reason behind the adoption of four cylinders in a triple-expansion engine. In this system of balancing, no weights or other external appliances were used to balance the reciprocating and rotating masses. Instead, vibration was reduced or eliminated by carefully balancing the power impulses and turning moments of each cylinder and crank throw one against the other, the necessary counter-forces being obtained by adjustment

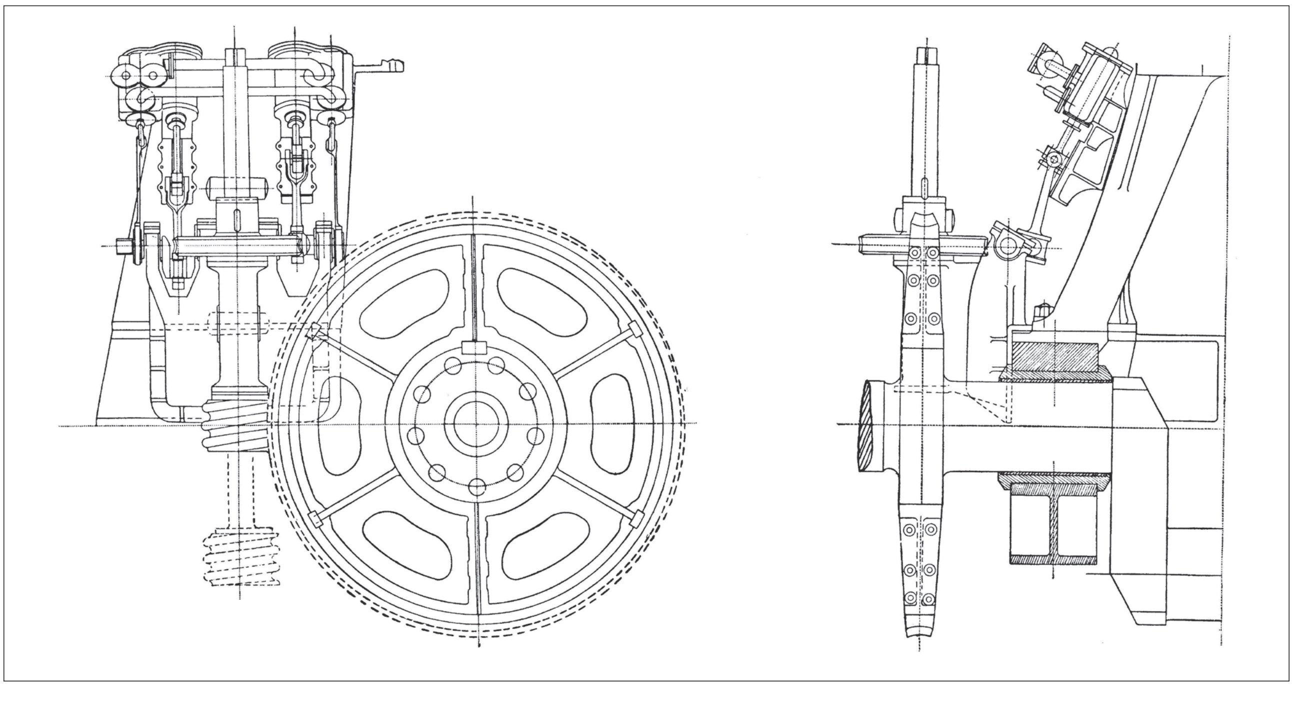


Fig. 15-37 **Turning Engine** – Detailed illustration of a turning engine as fitted to the main reciprocating engines. *(Scott Andrews collection)*

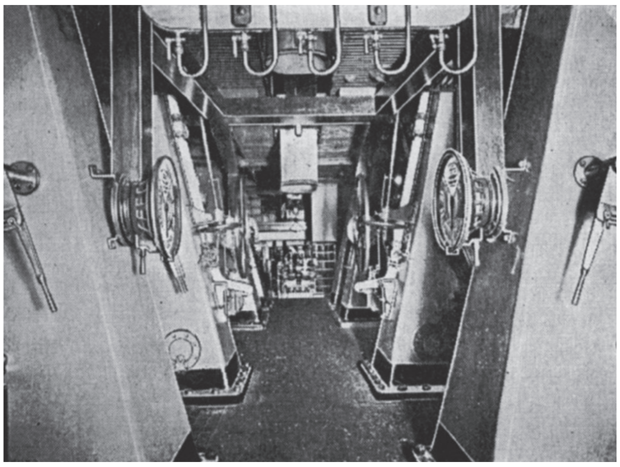


Fig. 15-38 **Engine Room Starting Platform, SS *Nieuw Amsterdam*** – Shown here is the starting platform of the Holland America Line's H&W-built SS *Nieuw Amsterdam* (1905). Though the machinery is quite a bit smaller, this gives a good general impression of what this space looked like on the *Olympic*-class liners. The engine order telegraphs and the throttle controls of the reciprocating engines were of the same configuration. *(*Engineering*/Scott Andrews collection)*

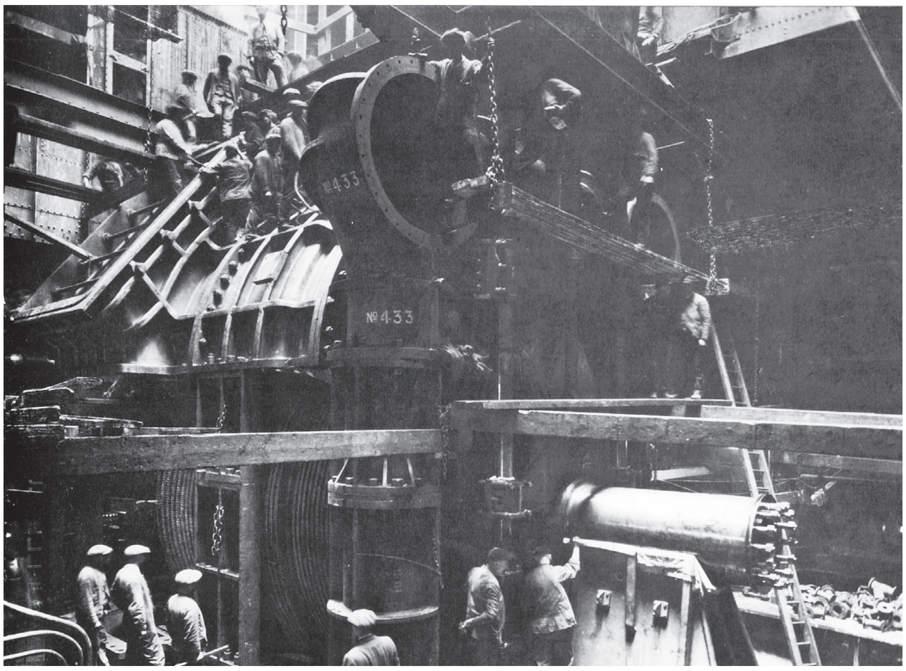


Fig. 15-39 **Turbine Engine Being Fitted Aboard Ship** – The turbine engine undergoing final assembly aboard *Britannic. (H&W/Authors' collection)*

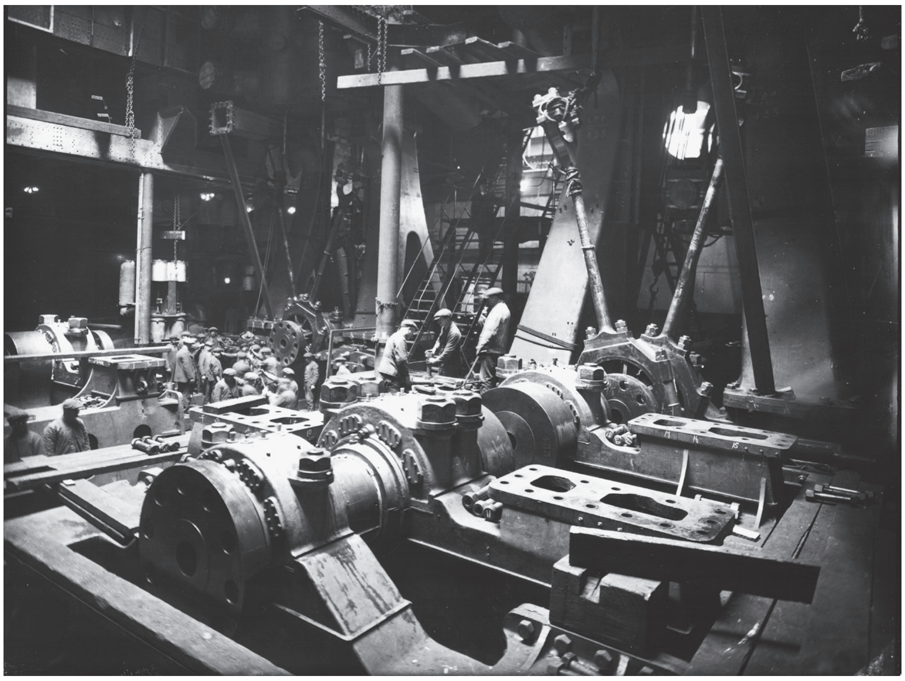


Fig. 15-40 **Reciprocating Engines Being Fitted Aboard Ship** – The reciprocating engines undergoing final assembly aboard *Britannic.* At the after end of the Reciprocating Engine Room, daylight streams through the large holes which the shipfitters have cut through WTB 'L' for passage of the main exhaust pipes which will supply exhaust steam to the low-pressure turbine. In the center of the picture, the double ladders and mid-level landing which provided access to the middle and upper levels of the engine room have already been installed. *(*Engineering*/ Authors' collection)*

of the relative crank angles and crank sequence, or order of rotation. In the case of *Titanic*'s engines, the crank sequence and angle, beginning with the high-pressure crank at top dead center, was as follows: (1) H.P.; then, 106° rotation to (2) I.P.; then, 100° rotation to (3) L.P. (forward); then 54° rotation to (4) L.P. (aft); then 100° rotation, returning to H.P. at top dead center.

From the photographs and drawings, it will be seen that the cylinder support columns were of the double 'split' type, each column near its center being divided into two sections that were spread out in the form of an inverted 'Y' in order to form a strong base. Each of these columns was of cast steel and weighed 21 tons. They were arranged in pairs astride the crankshaft beneath the cylinders. Attached to flanges and gussets cast integral with the upper inboard leg of each column were the crosshead guides. The crosshead guides were of the 'open' type and were cast steel, lined on the bearing faces with

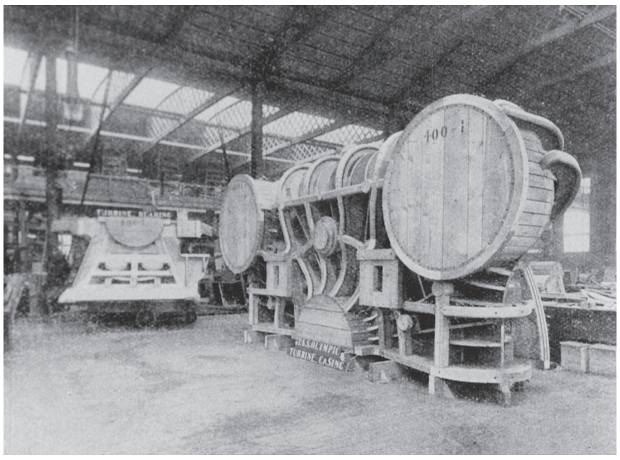


Fig. 15-43 **Wooden Patterns for Turbine Casing –** Patterns for the castings for the steam receiver (right) at the forward end of the upper half of the turbine case, and (left) the lower after bearing support for *Olympic*. (The Shipbuilder*/Authors' collection)*

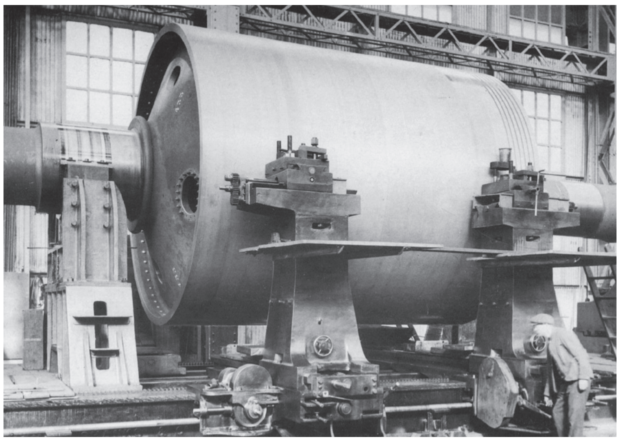


Fig. 15-41 ***Britannic* Rotor in the Lathe** – Here, grooves are cut into the face of the rotor drum to accept the rings containing the blades. Note the difference in the shop machinery when compared to the picture of the rotor for *Olympic* undergoing the same process; the work on *Britannic*'s turbine was carried out in the then-new H&W Turbine Engine Shops. (The Engineer/ *Authors' collection)*

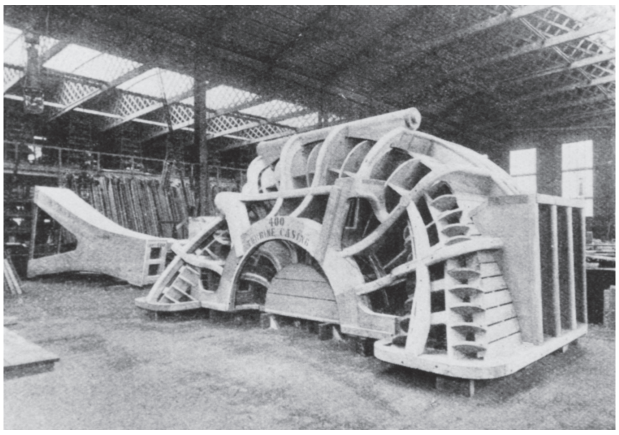


Fig. 15-44 **Wooden Patterns for Turbine Casing** – Pattern for the casting for the lower after end of the turbine casing for *Olympic.* Here, the pattern is in the inverted position. In the background is a pattern for one of the low-pressure cylinder columns for the reciprocating engines. (The Engineer/*Authors' collection)*

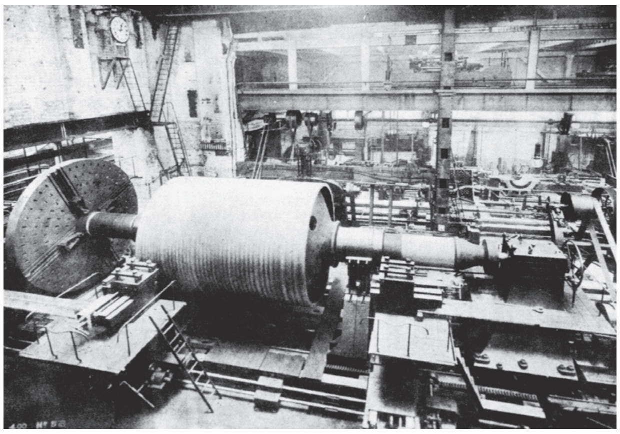


Fig. 15-42 **Turbine Rotor in the Lathe** – *Olympic*'s turbine rotor being 'grooved' in the lathe. (The Shipbuilder/*Authors' collection)*

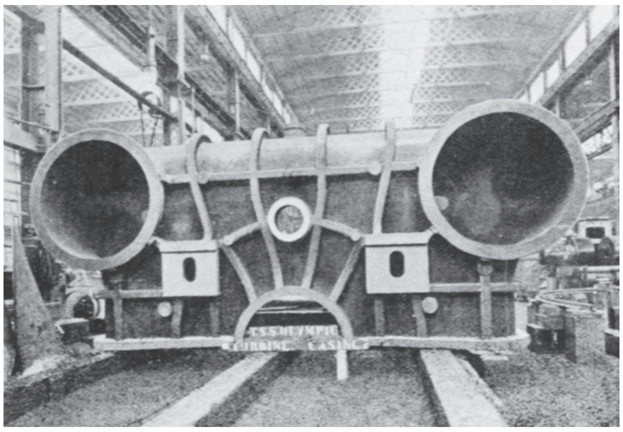


Fig. 15-45 **Turbine Case Casting** – The completed casting for the steam receiver at the forward upper end of the turbine case for *Olympic*. (The Engineer/*Authors' collection)*

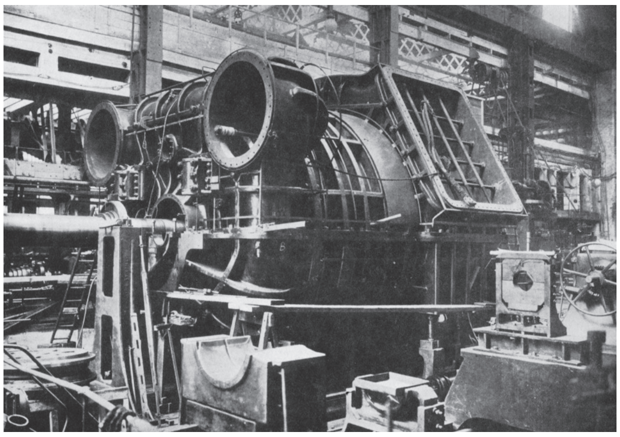


Fig. 15-46 **Turbine Case Being Machined** – The assembled castings for *Olympic*'s turbine case undergoing final machining operations. (The Engineer/*Authors' collection)*

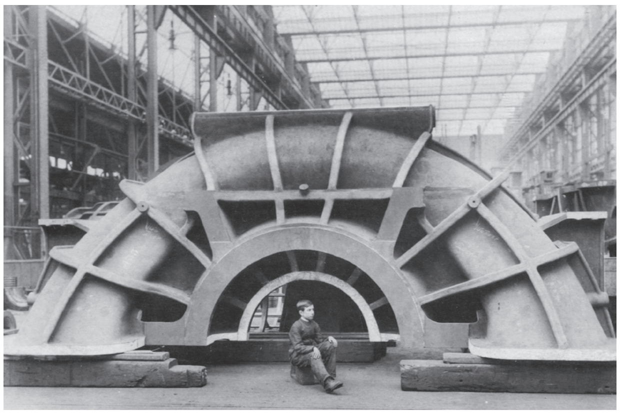


Fig. 15-47 **Turbine Case Casting** – The completed casting for the lower after end of *Britannic*'s turbine casing, shown here laying inverted. (The Engineer/*Authors' collection)*

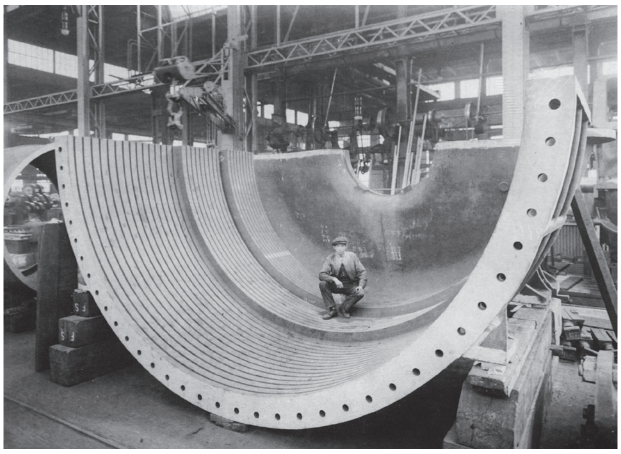


Fig. 15-48 **Turbine Case Casting** – The completed casting for the lower forward end of *Britannic*'s turbine casing in the shop. (The Engineer/*Authors' collection)*

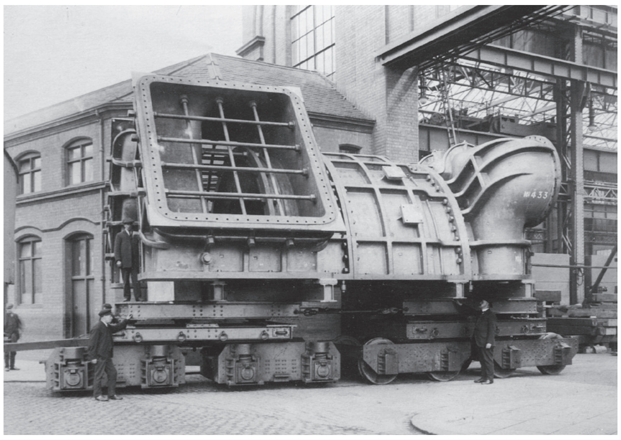


Fig. 15-49 **Upper Turbine Case** – The assembled upper half of *Britannic*'s turbine casing on the tram. (The Engineer/*Authors' collection)*

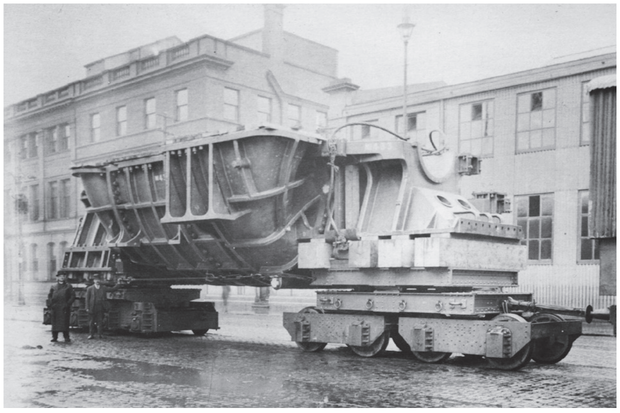
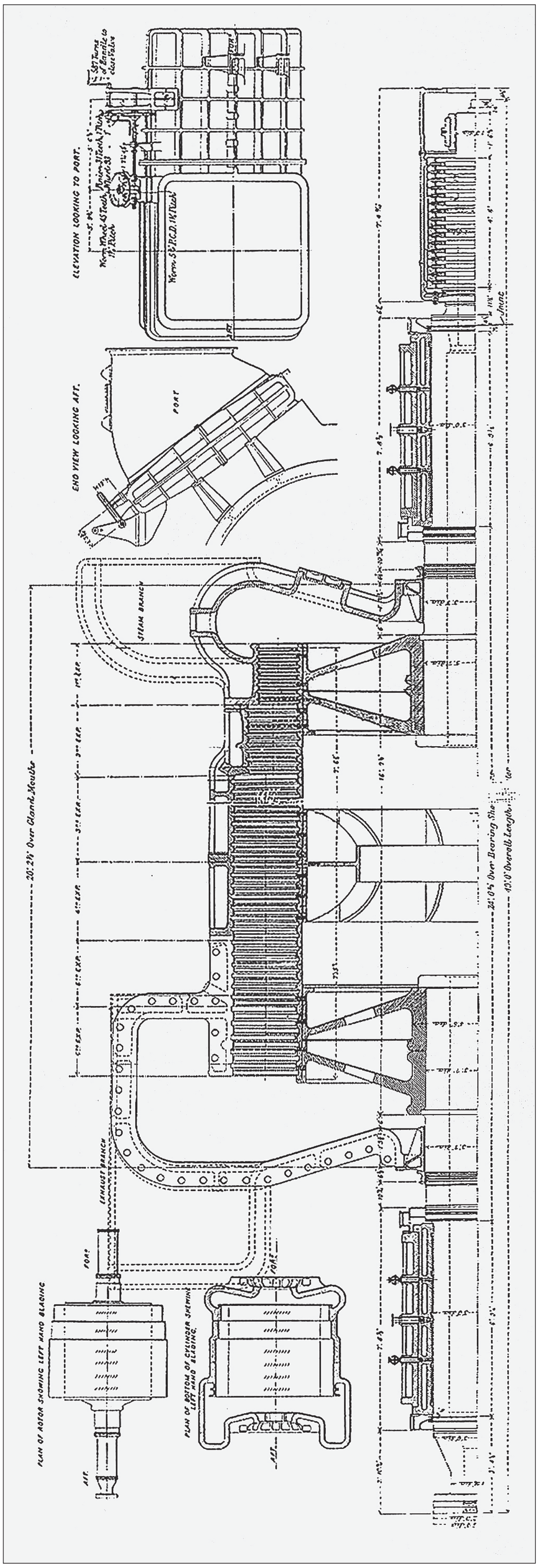


Fig. 15-50 **Lower Turbine Case** – The assembled lower half of *Britannic's* turbine casing on the tram. (The Engineer/*Authors' collection)*

white metal. The 'ahead' and 'astern' guides were of equal size, a practice Harland & Wolff adopted early in their experience in constructing large engines. Grooves or 'gutters' of a pattern designed to promote the spreading of oil were let into the bearing faces of these guides to ensure complete lubrication of the guides. A trough at the base of each guide was provided to catch the spent oil, which then drained to collection tanks for reuse.

Mounted on top of the support columns were the cylinders. The cylinder casings, being castings of a complex nature, were in all cases of a type of soft cast iron that was found suitable for running freely in the molds. Ribs were incorporated horizontally around the top and bottom edges as well as midway in between. These provided additional strength to the castings, as well as providing both a raised surface to affix the external galvanized sheet iron sheathing and space to fill with insulation, or 'lagging'. The type of cast iron used in the casings was, however, too soft to be suitable for wear surfaces. This included surfaces such as the cylinder barrel, or 'liner', in which the piston worked; and the cylinder slide face, or 'false face', on which slide valves worked. The cylinder liners and slide-valve faces were of hard, close-grained cast iron. The piston-valve liners were of brass, each of these liners actually being in two pieces


ELEVATION LOOKING TO PORT.
END VIEW LOOKING AFT.
PORT
STEAM BRANCH
EXHAUST BRANCH
PLAN OF ROTOR SHOWING LEFT HAND BLADING
PLAN OF BOTTOM OF CYLINDER SHOWING LEFT HAND BLADING.
AFT.
20'-2½" Over Gland Mouths

Left Fig. 15-51 ***Britannic* Turbine illustration** – This figure illustrates the turbine and sluice valves fitted to *Britannic*. The drawing serves to illustrate the machinery of *Olympic* and *Titanic* as well. While the diameter of the rotor drum and the length of the blades were increased on the third ship, the dimensions of many of the key components and the number of expansion stages remained the same. Comparison with the dimensions given within this chapter will point out the major differences. Note also that the sluice valves of *Britannic* were fitted with a hand-operating gear only, instead of the electric motor-driven gear employed on *Olympic* and *Titanic*. *(*The Engineer*/Authors' collection)*

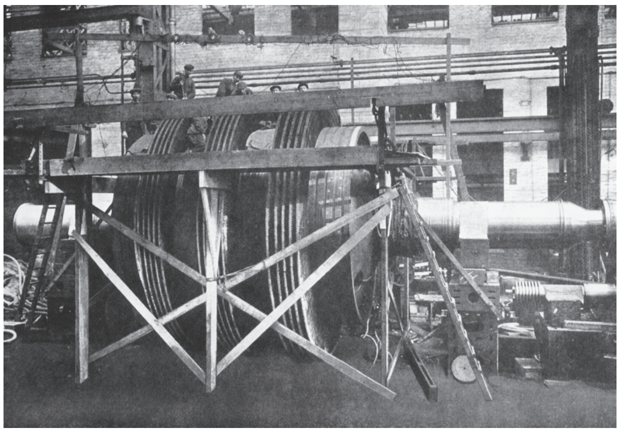


Fig. 15-52 **Turbine Rotor in Process of Blading** – *(*The Shipbuilder*/Authors' collection)*

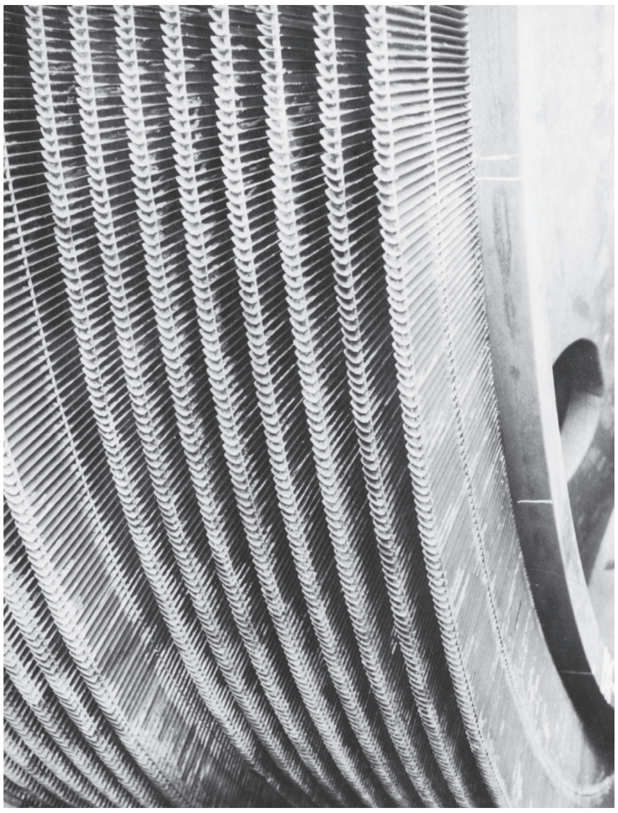


Fig. 15-53 **Detail of Blading** – Detail of the blading of *Britannic*'s turbine rotor. *(H&W/Authors' collection)*

– an upper and lower liner. The heaviest cylinder with liner weighed about 50 tons. The pistons, in all cases, were of cast steel and had a tapered hole bored through the center to accept the upper end of the piston rod, onto which they were securely fastened by a large nut and set pins. The pistons were fitted with Lockwood and Carlisle's rings, except in the case of the high-pressure cylinder where Ramsbottom rings were applied.

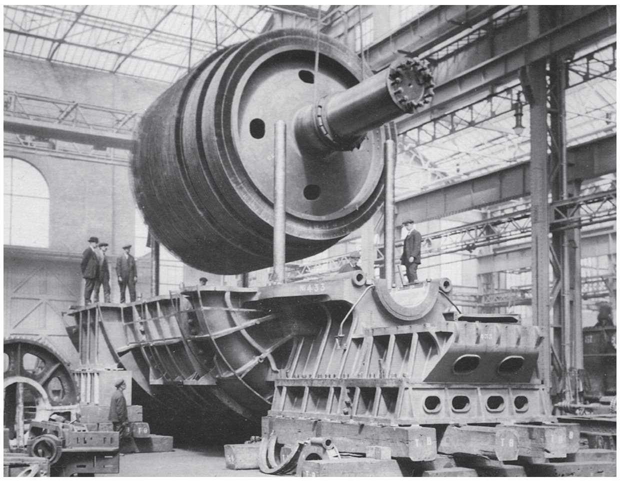


Fig. 15-54 **Test-Fitting the Rotor** – Test-fitting *Britannic*'s turbine rotor in the case. The four large pillar-like guide pins rising from the lower case have been temporarily installed to help accurately guide the upper case while the overhead cranes lower it into position. *(H&W/Authors' collection)*

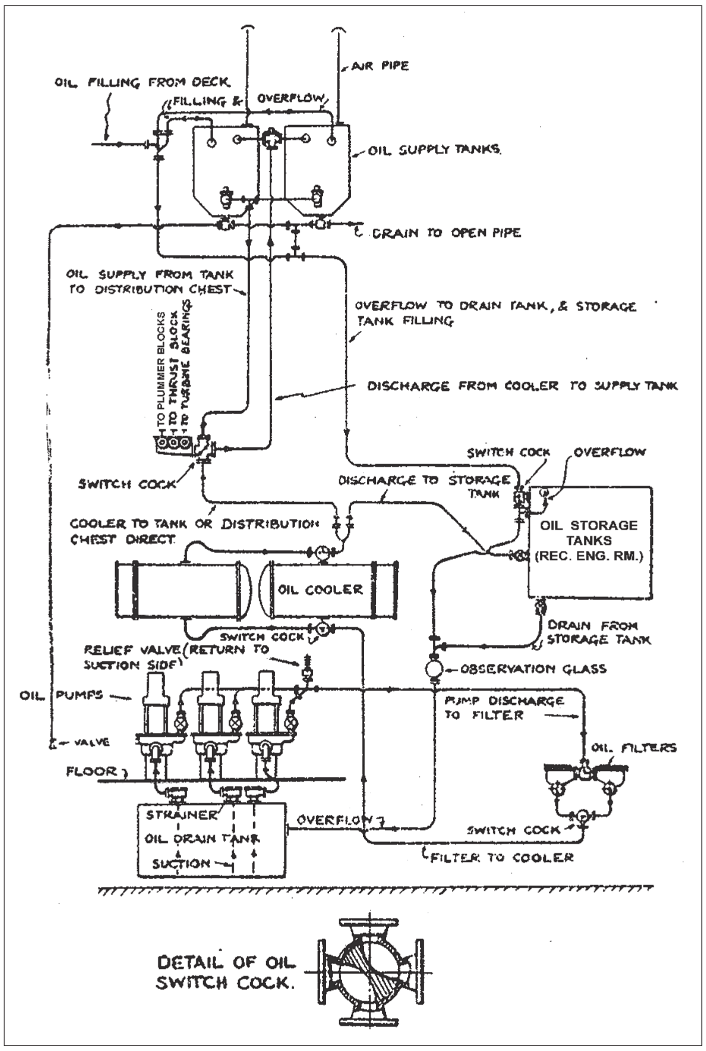
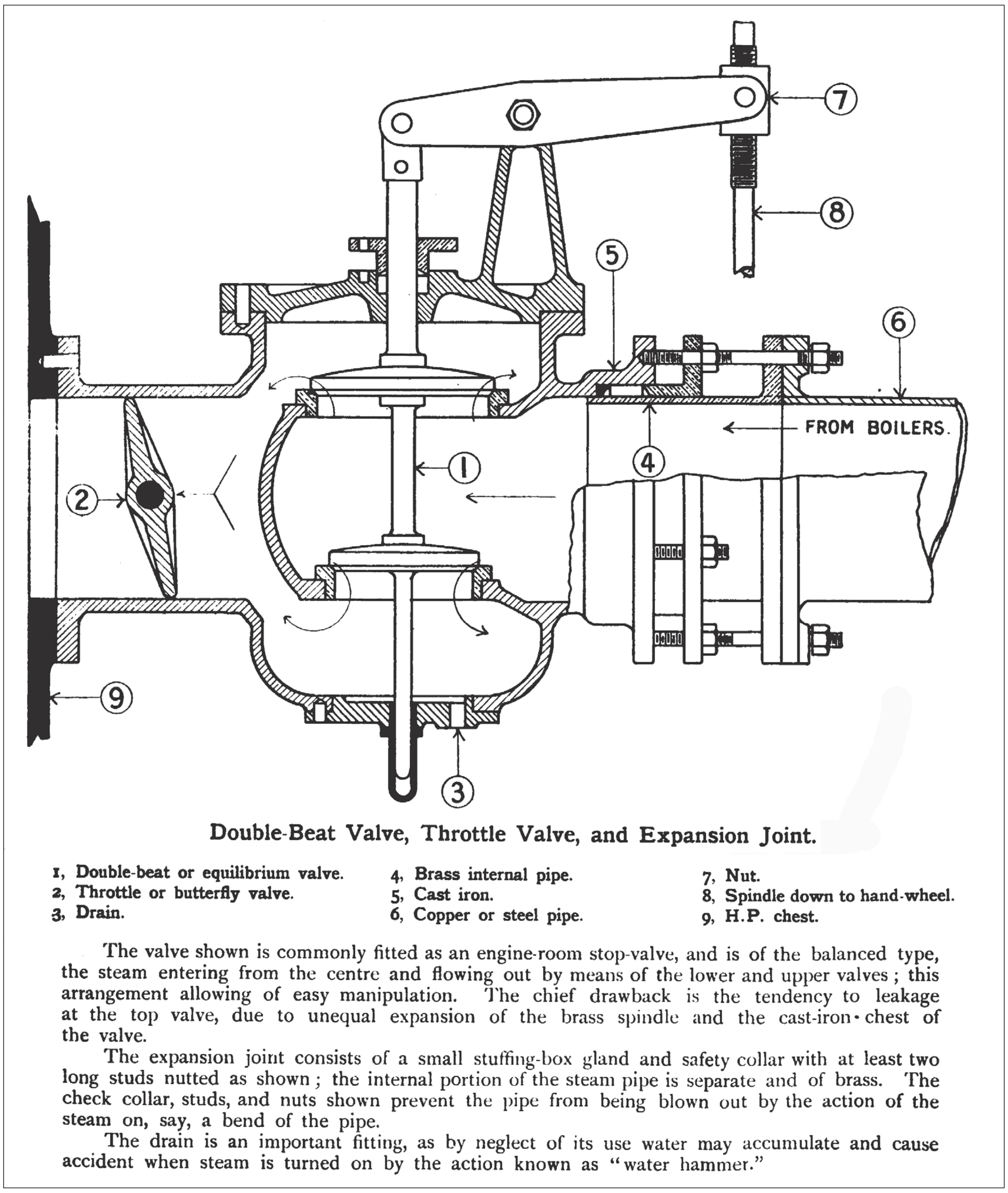

AIR PIPE
OIL FILLING FROM DECK
FILLING & OVERFLOW
OIL SUPPLY TANKS.
DRAIN TO OPEN PIPE
OIL SUPPLY FROM TANK TO DISTRIBUTION CHEST
TO PLUMMER BLOCKS
TO THRUST BLOCK
TO TURBINE BEARINGS
OVERFLOW TO DRAIN TANK, & STORAGE TANK FILLING
DISCHARGE FROM COOLER TO SUPPLY TANK
SWITCH COCK
OVERFLOW
SWITCH COCK
DISCHARGE TO STORAGE TANK
COOLER TO TANK OR DISTRIBUTION CHEST DIRECT
OIL STORAGE TANKS (REC. ENG. RM.)
OIL COOLER
SWITCH COCK
DRAIN FROM STORAGE TANK
RELIEF VALVE (RETURN TO SUCTION SIDE)
OBSERVATION GLASS
OIL PUMPS
PUMP DISCHARGE TO FILTER
VALVE
OIL FILTERS
FLOOR
STRAINER
OIL DRAIN TANK
SUCTION
OVERFLOW
SWITCH COCK
FILTER TO COOLER
DETAIL OF OIL SWITCH COCK.

Fig. 15-55 **Forced-Lubrication System** – Schematic diagram showing the general outline of the type of forced-lubrication system employed in the *Olympic*-class liners.

The piston rods and connecting rods were of exceptionally stout construction, forged of high-tension steel. The diameter of the high-pressure and intermediate-pressure piston rods was 14in, and those of the low-pressure cylinders 11¾in. The connecting rods, which were of the double top-end type, had a length 14ft ¾in, or 2¼ times the stroke. The bodies of the high-pressure and intermediate-pressure connecting rods were tapered from 13½in in diameter at the top to 15in at the bottom; in the case of the low-pressure rods the diameter was 2in less.

The connection between the piston rods and connecting rods was made by means of an assembly called a 'crosshead'. This was comprised of a gudgeon block and pins, to which were bolted the crosshead bearings, also known as 'slippers' or 'guide shoes'. This assembly worked between the crosshead guides attached to the support columns, guiding and centering the lower end of the piston rod while transmitting the reciprocating motion of the piston rod to the connecting rod. Simultaneously the crosshead assembly also transmitted the side thrust of the connecting rod via the crosshead bearings to the crosshead guides on the support columns. The gudgeon block and pins were made integral with each other and were of forged steel. The pins were 16½in in diameter and 17¼in long in the case of the high-pressure and intermediate-pressure cylinders, while those of the low-pressure cylinders were 3in less in each case. A tapered hole was bored through the gudgeon block allowing the crosshead to be fixed to the bottom end of the piston rod in the same manner as was the piston to the top. The gudgeon pins worked the connecting rods through white-metal-lined bearings, which were held between bearing blocks and bolted to the forks at the top end of the connecting rods.

In each set of engines, the high-pressure cylinder was provided with a single piston valve, while the intermediate-pressure cylinder was provided with two piston valves worked from a common crosshead by a single set of double bar links and eccentrics. The piston valves, in all cases, were fitted with rings of the Lockwood and Carlisle type. Each low-pressure cylinder was provided with two slide valves of the double-ported type, operated in a similar manner to the twin piston valves on the intermediate-pressure cylinder. These slide valves, owing to their great size and weight, were fitted with equilibrium or 'relief' rings at the back sides to reduce



Double-Beat Valve, Throttle Valve, and Expansion Joint.

1, **Double-beat or equilibrium valve.**
2, **Throttle or butterfly valve.**
3, **Drain.**
4, **Brass internal pipe.**
5, **Cast iron.**
6, **Copper or steel pipe.**
7, **Nut.**
8, **Spindle down to hand-wheel.**
9, **H.P. chest.**

The valve shown is commonly fitted as an engine-room stop-valve, and is of the balanced type, the steam entering from the centre and flowing out by means of the lower and upper valves; this arrangement allowing of easy manipulation. The chief drawback is the tendency to leakage at the top valve, due to unequal expansion of the brass spindle and the cast-iron chest of the valve.

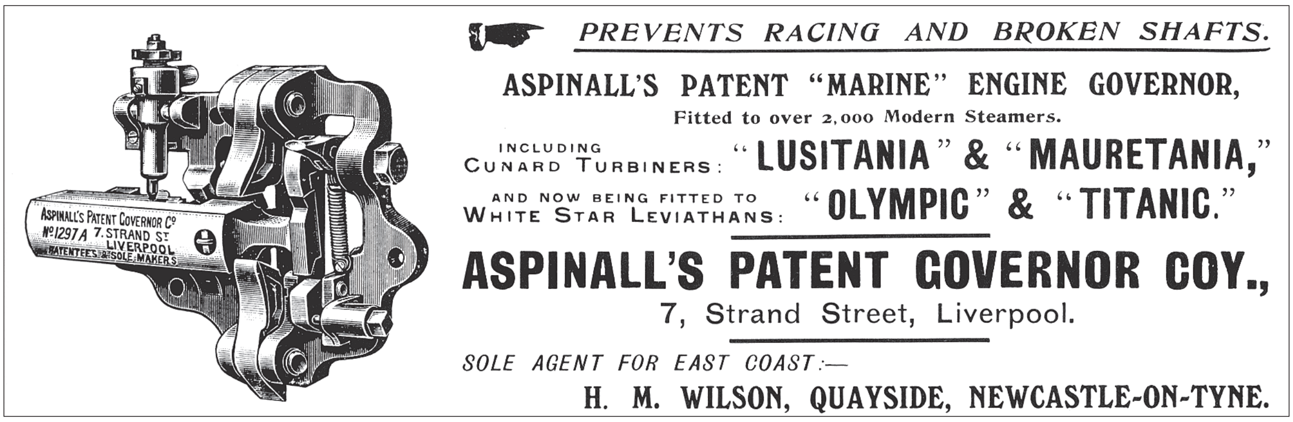
The expansion joint consists of a small stuffing-box gland and safety collar with at least two long studs nutted as shown; the internal portion of the steam pipe is separate and of brass. The check collar, studs, and nuts shown prevent the pipe from being blown out by the action of the steam on, say, a bend of the pipe.

The drain is an important fitting, as by neglect of its use water may accumulate and cause accident when steam is turned on by the action known as "water hammer."

Fig. 15-56 **Main Stop Valve** – This figure illustrates the principal components of the main stop and throttle valves of the reciprocating engines. Note the expansion joint incorporated into the valve case at the inlet connection. Not shown in this section view is the smaller by-pass valve incorporated into one side of the valve case, which was used for low speed maneuvering. *(Scott Andrews collection)*

friction between the slide valve and valve face, as well as each slide valve being fitted with a balance piston at the top. The relief rings, which were fitted into the back side of the slide-casing cover, were situated between the back face of the valve and a chamber in the slide-casing cover. The chamber was connected to the exhaust steam pipe from the low-pressure cylinders, which caused a slight vacuum to be induced. This vacuum pulled back on the slide valve against the force of the incoming steam, which tended to press the valve tightly against the valve face. The balance pistons were arranged to take much of the weight of these valves off of the links and eccentrics by similar means. Small cylinders with pistons were fitted on top of the slide casing above each slide valve, the pistons being attached to an upper extension of the valve spindle that operated the valve. The top portion of this cylinder was connected to the exhaust steam pipe of the low-pressure cylinders, while the bottom of the cylinder was in communication with the interior of the slide casing, and in turn the higher pressure incoming steam exhausted from the intermediate-pressure cylinder. The effect of this pressure differential on the piston nearly negated the forces on the eccentrics and links caused by the weight of the valves.

The valves were operated by Stephenson's link motion. The valve spindles, link bars, drag rods, reversing, or


ASPINALL'S PATENT GOVERNOR Co
No 1297A 7. STRAND St
LIVERPOOL
PATENTEES & SOLE MAKERS

PREVENTS RACING AND BROKEN SHAFTS.

ASPINALL'S PATENT "MARINE" ENGINE GOVERNOR,
Fitted to over 2,000 Modern Steamers.
INCLUDING CUNARD TURBINERS: "LUSITANIA" & "MAURETANIA,"
AND NOW BEING FITTED TO WHITE STAR LEVIATHANS: "OLYMPIC" & "TITANIC."
ASPINALL'S PATENT GOVERNOR COY.,
7, Strand Street, Liverpool.
SOLE AGENT FOR EAST COAST:—
H. M. WILSON, QUAYSIDE, NEWCASTLE-ON-TYNE.

Fig. 15-57 **Advertisement for Aspinall's Patent Governor**. *(*The Shipbuilder*/Authors' collection)*

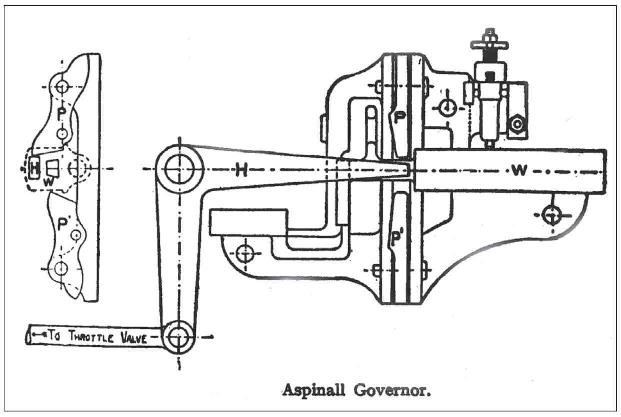


Fig. 15-58 **The Aspinall Governor – Principal Parts and Function** – The Aspinall governor consisted of a weight W which was hinged to allow it to swing past its normal travel when an increase in speed of approximately 5 per cent beyond that for which the engine was set was reached. Due to its inertia, the weight moved beyond its normal range of travel, causing the shutting pawl P to engage the throttle lever H, moving the throttle valve rod to the 'closed' position; this caused the throttle engine to close the throttle plate. This operated until the engine had slowed to normal speed where weight W returned to its normal position, disengaging pawl P and engaging pawl P1 which engaged lever H to reopen the throttle plate. The sensitivity of the governor was adjusted with the set screw S. A special safety device which worked on the same principal as weight W was also fitted, which would shut the throttle and not allow it to automatically reopen; this was activated by a sudden acceleration such as a broken shaft or a dropped propeller would cause. *(Scott Andrews collection)*

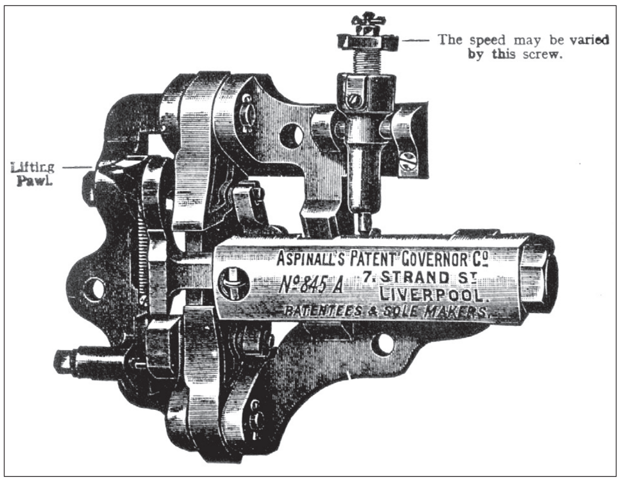

The speed may be varied by this screw.
Lifting Pawl.
ASPINALL'S PATENT GOVERNOR Co
No 845 A 7. STRAND St
LIVERPOOL
PATENTEES & SOLE MAKERS

Fig. 15-59 **Aspinall's Governor for Reciprocating Steam Engines**. *(Scott Andrews collection)*

'wyper' shaft and levers, eccentric rods, eccentric straps, and associated parts were all of forged steel, the straps being lined with a white-metal bearing surface. The remaining components of the valve gear were of cast steel, and fitted with brass bushes and bearing surfaces. The reversing gear for each set was operated by a Brown's engine, about which more will be said later. In order that the reversing engine would always be at full stroke regardless of the steam cut-off required in each cylinder, each set of links had a separate adjustment.

Located on the after-most outboard support column of each engine set was a steam-driven turning engine.

The turning engines were provided to turn over the crankshaft and other moving parts of the engine during maintenance and repairs, as well as being used to move the engines on a daily basis during periods of idleness. In addition, the turning engines were used to slowly turn over the engines during the pre-departure warm-up of the internal components of the cylinders and during cooling-down at the completion of a voyage. Each turning engine was of the double-cylinder type, each cylinder having a diameter of 10in and a stroke of 10in. Turning engines of this type were designed to move a main engine through one complete revolution within eight minutes. Through a worm-and-wheel arrangement, the turning engine rotated a vertical shaft on which was mounted a larger worm gear arranged to slide into and out of engagement with the large worm-wheel on the end of each crankshaft. For occasions when steam was not available, arrangements were provided for manually turning each of the reciprocating engines by means of bar and ratchet.

Two overhead hoists on trolleys, each powered by a 6BHP electric motor, were provided for the lifting of

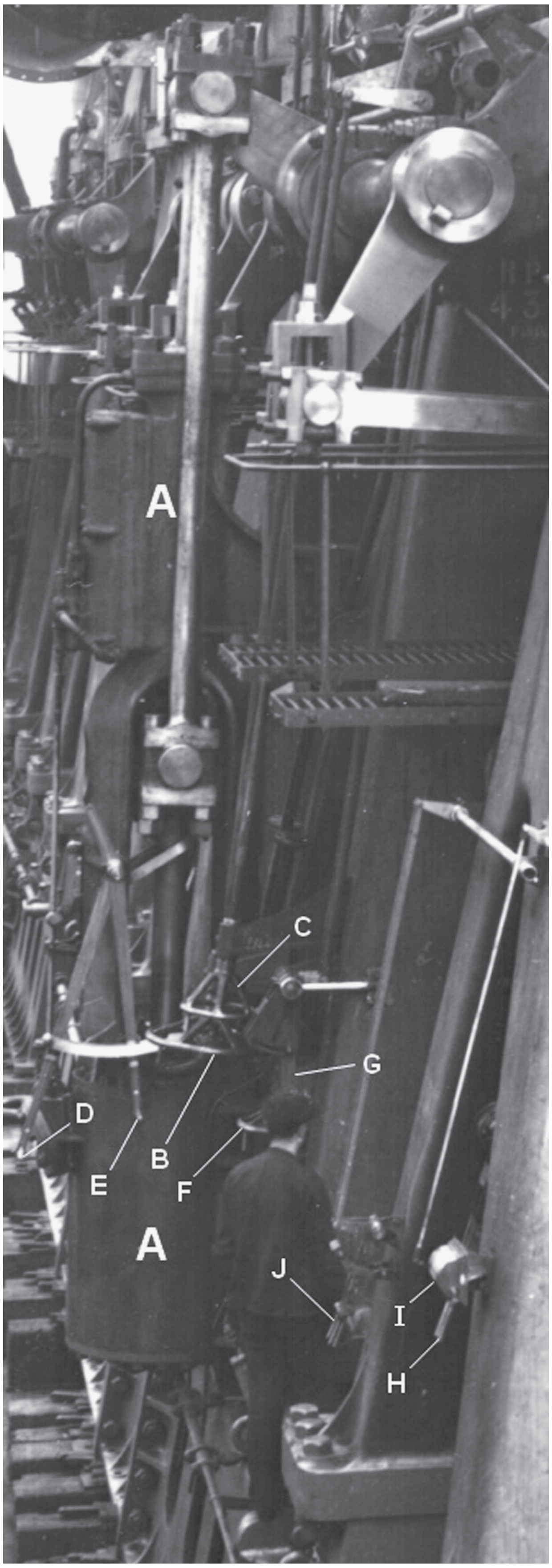


Fig. 15-60 **Reversing Engine and Main Engine Controls at the Starting Platform Level** – Port engine of *Britannic* pictured; except as indicated, the starboard engine had an identical, independent set of controls. *(Scott Andrews collection)*

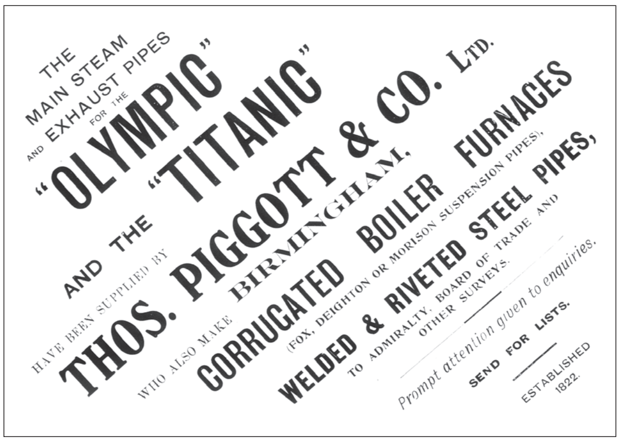
(a) Reversing engine (Drag links and valve linkage are in the 'astern' position)
(b) Main stop valve handwheel (Main Throttle Control)
(c) By-pass valve handwheel (Low Speed 'Maneuvering' Throttle Valve)
(d) Reversing lever (lever shown in 'astern' position)
(e) Turbine change-over valve lever (port station only) (lever shown in 'cut-out' position)
(f) Turbine starting valve (port station only) (used to momentarily inject high pressure steam to assist in bringing the turbine up to speed)
(g) LP and IP cylinder starting valve levers (used when necessary to start engine when it has stopped with the HP cylinder inlet valve in the 'closed' position, and condenser vacuum fails to pull the crankshaft off of this position)
(h) HP and forward LP cylinder drain levers (for draining off condensed warming steam prior to starting; similar levers for IP and after LP cylinders located beneath the IP cylinder)
(i) Engine revolution counter (for tracking total revolutions accumulated during a specified period of time)
(j) Emergency stop valve levers (used to close the quick-acting valves located on the main steam lines at the forward side of WTB 'K'; levers for both P & S valves duplicated on both engines)

the cylinder covers and other heavy components, which were routinely opened up or removed for inspection, maintenance and repair. These hoists were necessary owing to the great weights to be handled. Each set of gears was supported by, and traveled on, two parallel heavy I-beams that were fixed to the undersides of the beams of the Saloon Deck (D). In addition to the overhead hoisting machinery, several electric winches were provided to deal with the smaller weights.

Within the Reciprocating Engine Room there was a well-equipped Engineer's Workshop. This was situated on the starboard side on a flat above the Engine Room wing at the level of the Lower Deck (G), and occupied the area from the after bulkhead of the Reciprocating Engine Room to a place about two-thirds of the way towards the forward bulkhead. The workshop had a large lathe, shaping machine, drilling machine, grindstone, emery wheel and other tools which were operated from an overhead shaft via belts driven by a 7½BHP electric motor.

Exhaust steam turbine

The turbine driving the center shaft was of the Parsons low-pressure exhaust type and was designed to take steam from the two reciprocating engines at a pressure of about 9PSIA. This steam was then expanded down to a pressure of about 1PSIA, this expansion being accomplished in approximately six stages, and with the condensing plant operating at about 28 to 28½in vacuum. This was among the largest marine exhaust turbines ever made, being superseded in size only by



THE MAIN STEAM AND EXHAUST PIPES FOR THE "OLYMPIC" AND THE "TITANIC" HAVE BEEN SUPPLIED BY

THOS. PIGGOTT & CO. LTD.

BIRMINGHAM,

WHO ALSO MAKE CORRUGATED BOILER FURNACES

(FOX, DEIGHTON OR MORISON SUSPENSION PIPES),

WELDED & RIVETED STEEL PIPES,

TO ADMIRALTY, BOARD OF TRADE AND OTHER SURVEYS.

Prompt attention given to enquiries.

SEND FOR LISTS.

ESTABLISHED 1822.

Fig. 15-61 **Advertisement for Thomas Piggott & Co**. – This company was subcontracted to fabricate, amongst other things, the main exhaust pipes of the reciprocating engines. *(*The Shipbuilder*/Authors' collection)*

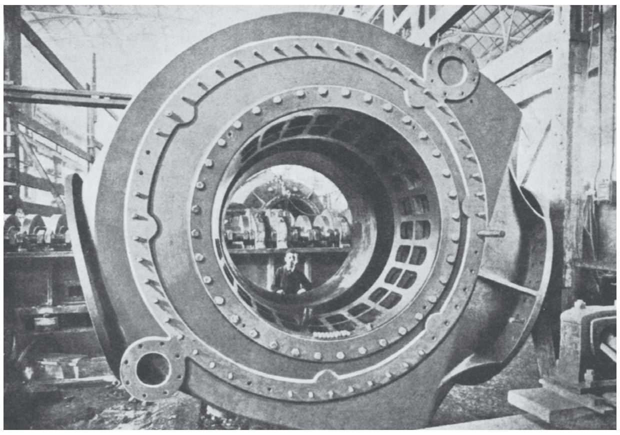


Fig. 15-62 **Casing of One of the Change-Over Valves**. *(*The Shipbuilder*/Authors' collection)*

the turbine built for *Britannic*. The overall length of the turbine was about 50ft, the rotor bladed weighing 130 tons; the total weight of the turbine complete being 410 tons. It was designed to develop approximately 16,000 shaft horsepower when running at 165RPM.

The rotor drum was of forged steel, in two pieces along the longitudinal line, and was manufactured by a special spinning process adopted at the Atlas Works, Sheffield, of John Brown & Co. Ltd. The diameter was 12ft and the length 13ft 8in between the extreme edges of the first and last ring of blades. A good impression of its size is afforded by Fig. 15-41, a view of *Britannic*'s rotor being turned in the lathe. The end wheels were of the solid disc type, made of cast steel and shrunk in and pinned in position. A large webbed stiffening wheel was fitted internally equidistant from the end wheels. The forged steel spindles were 3ft in diameter at the bearings and 3ft 7in in the wheels, followed by a short, quick taper to 21¼in where the aft spindle joined the line of shafting. Through each spindle was a 23in-diameter hole reduced to 11in at the tapered part. Bolted to the forward end of the rotor shaft was a forged steel thrust shaft of 24in in diameter and having seventeen collars, each 32in in diameter. This thrust shaft rode in a forged steel thrust block, the halves of which were grooved out to receive sixteen brass ring bearings, providing a total thrust surface of 5,000sq.in. The thrust block was arranged to 'float' in the direction parallel to the rotor axis to accommodate expansion of the rotor and turbine casing. The thrust absorbed by the thrust block was transmitted to the ship's structure through the lower half of the turbine

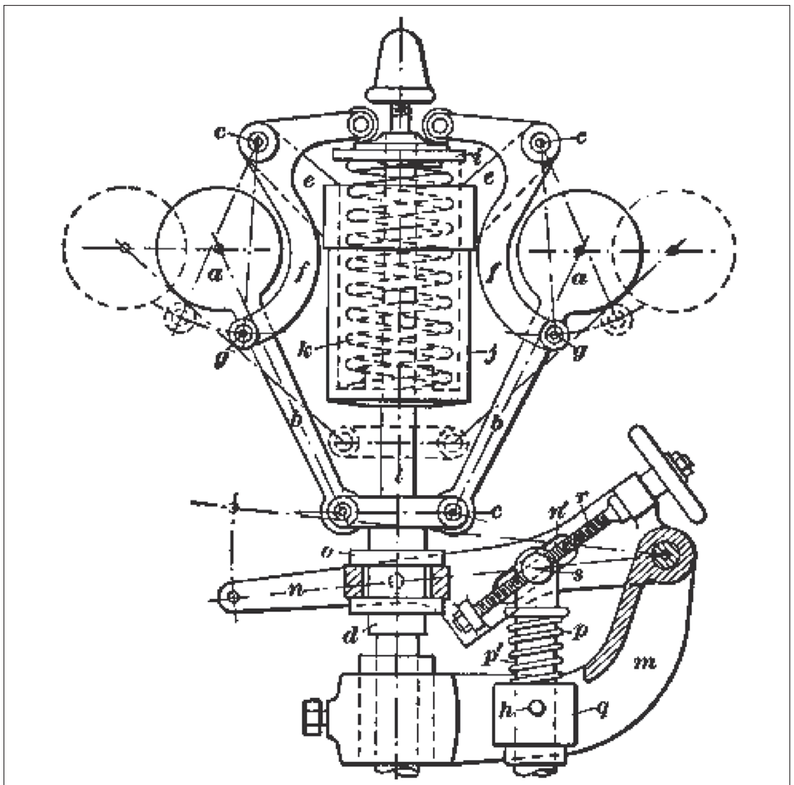


Fig. 15-63 **Proell Governor – Principal Parts** – This drawing illustrates the basic components of the Proell Governor. The dashed outline of the fly weights 'a' show their position as centrifugal force throws them outwards, gradually lifting throttle control lever 'n' which, if lifted too high, causes the Brown's engine controlling the changeover valves to redirect steam away from the turbine and directly into the condensers until the turbine's speed has dropped to the preset level of revolutions permitted. The threaded shaft and hand wheel move the fulcrum pin 's' to change the minimum number of revolutions the governor will permit, and therefore, the average number of revolutions at which the governor holds the turbine. It should be noted that this diagram shows the governor with the protective cover over the weights removed. *(Scott Andrews collection)*

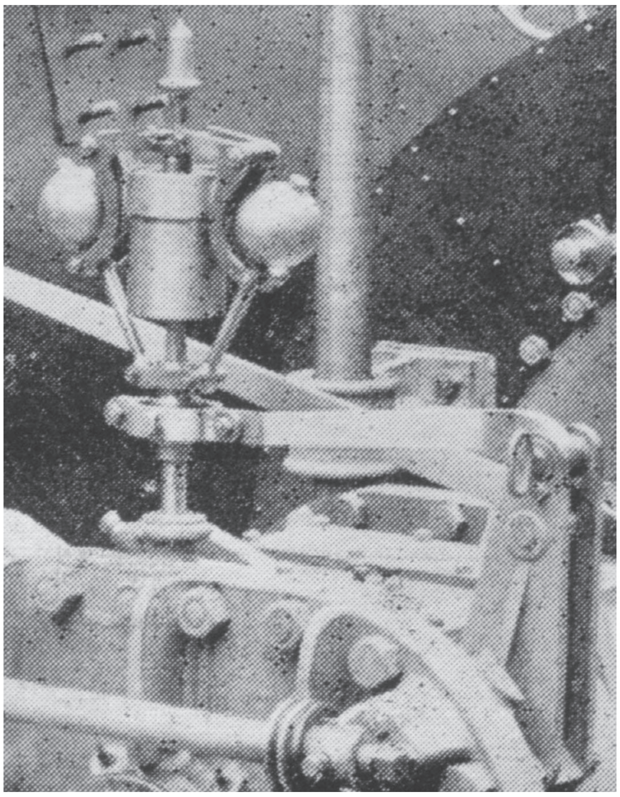


Fig. 15-64 **Proell Governor** – The Proell centrifugal governor as employed on the turbine. In this picture, the domed protective cover which normally enclosed the fly weights has been removed. *(Scott Andrews collection)*

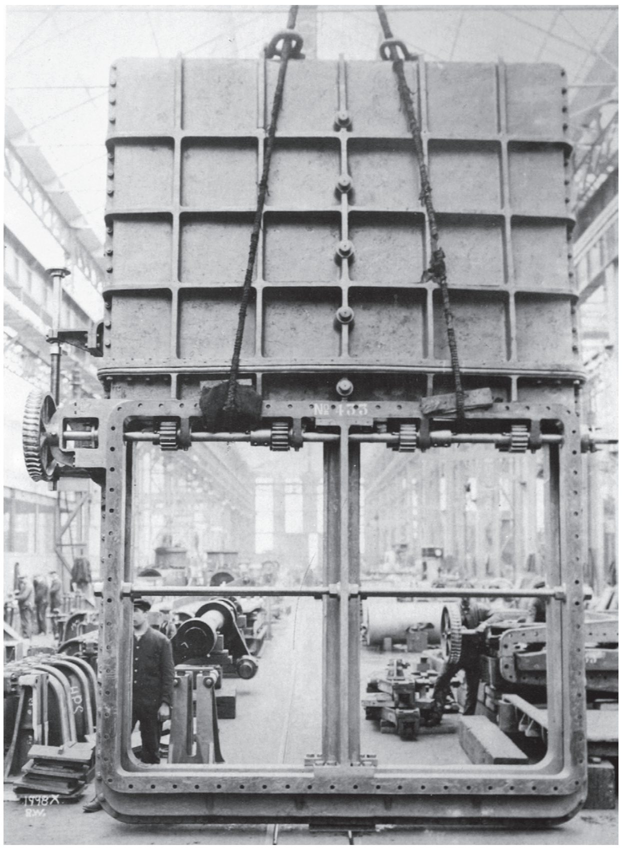


Fig. 15-65 **Sluice Valve** – One of *Britannic's* sluice valves shown in the shop at H&W. This image is frequently miscaptioned as being a watertight door assembly. *(H&W/Authors' collection)*

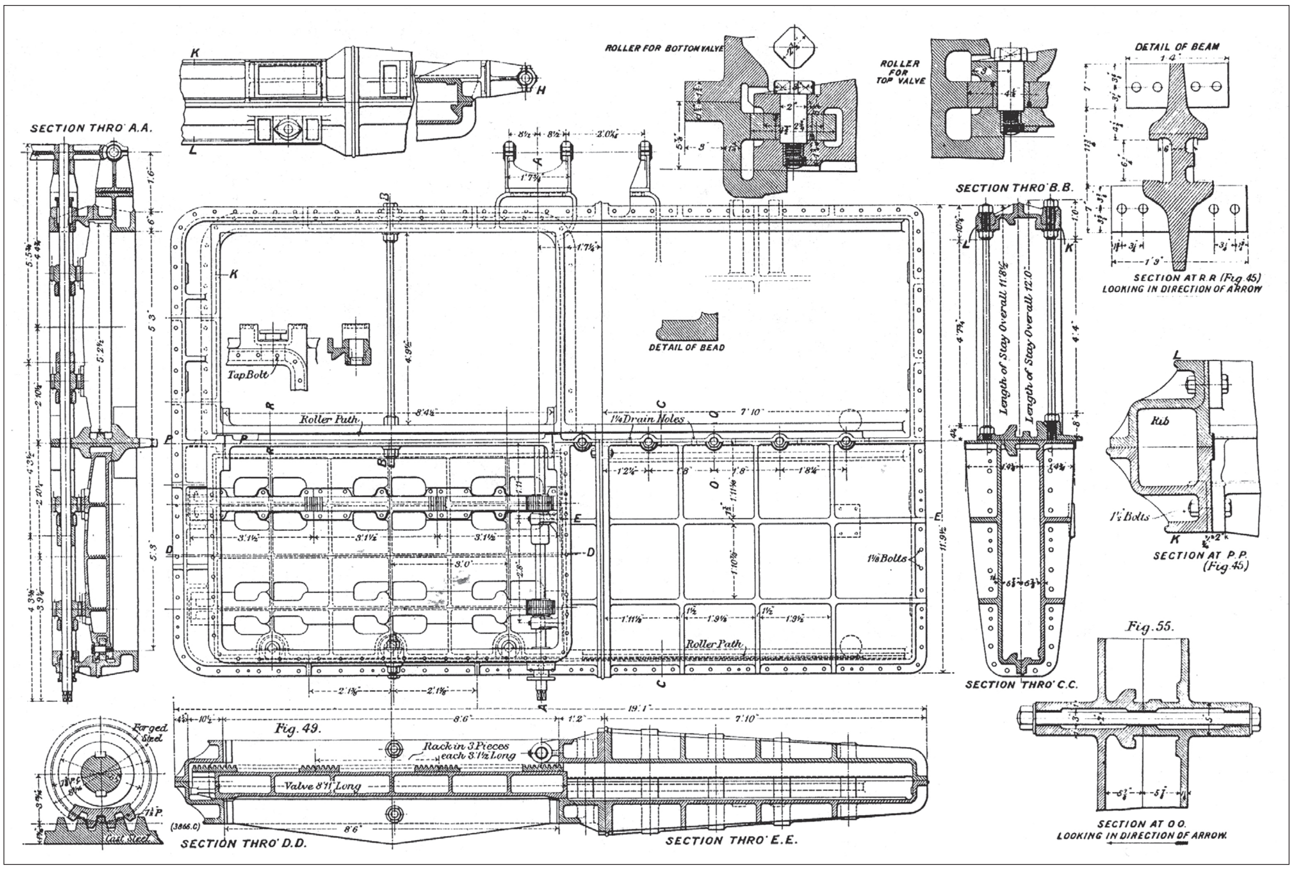

SECTION THRO' A.A.
ROLLER FOR BOTTOM VALVE
ROLLER FOR TOP VALVE
DETAIL OF BEAM
SECTION THRO' B.B.
SECTION AT R.R (Fig. 45) LOOKING IN DIRECTION OF ARROW
Length of Stay Overall 11'8½
Length of Stay Overall 12'0"
DETAIL OF BEAD
Tap Bolt
Roller Path
1¼ Drain Holes
1⅛ Bolts
Rib
1½ Bolts
SECTION AT P.P. (Fig. 45)
Fig. 55.
SECTION THRO' C.C.
Fig. 49.
Forged Steel
Cast Steel
Rack in 3 Pieces each 3'1½ Long
Valve 8'11" Long
(3866.C)
SECTION THRO' D.D.
SECTION THRO' E.E.
SECTION AT O.O. LOOKING IN DIRECTION OF ARROW.
K
L
H
A
B
C
D
E
P
R
O

Fig. 15-66 **Details of Sluice Valves Between Turbine and Condensers** – The figure illustrates one of *Britannic's* sluice valves. While *Britannic* was fitted with hand-operating gear instead of the electric motor-driven operating gear employed in *Olympic* and *Titanic*, the sluice valves on all three ships were otherwise identical. (Engineering/*Authors' collection)*

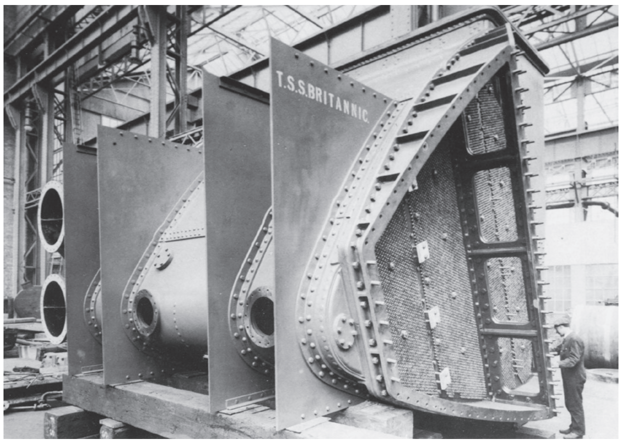


Fig. 15-67 **Main Condenser** – *Britannic*'s starboard main condenser in the shops, after end, with covers removed. *(H&W/Authors' collection)*

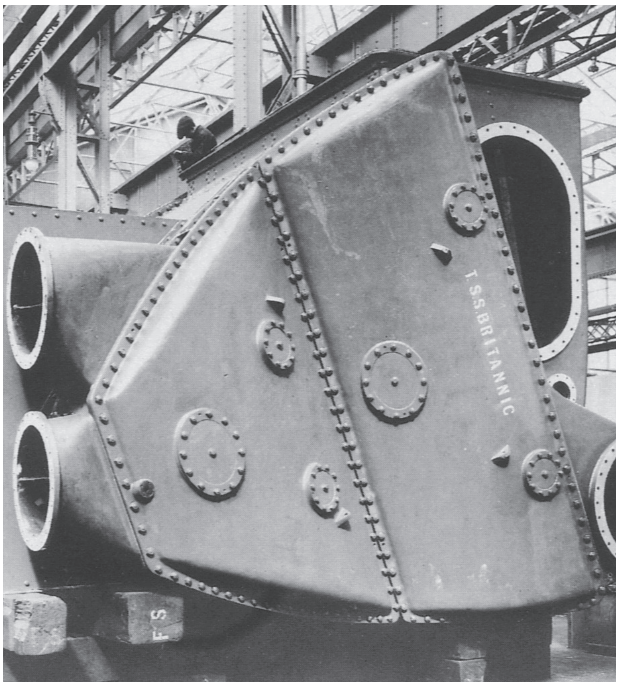


Fig. 15-68 **Main Condenser** – Port main condenser in the shops, forward end. *(H&W/Authors' collection)*

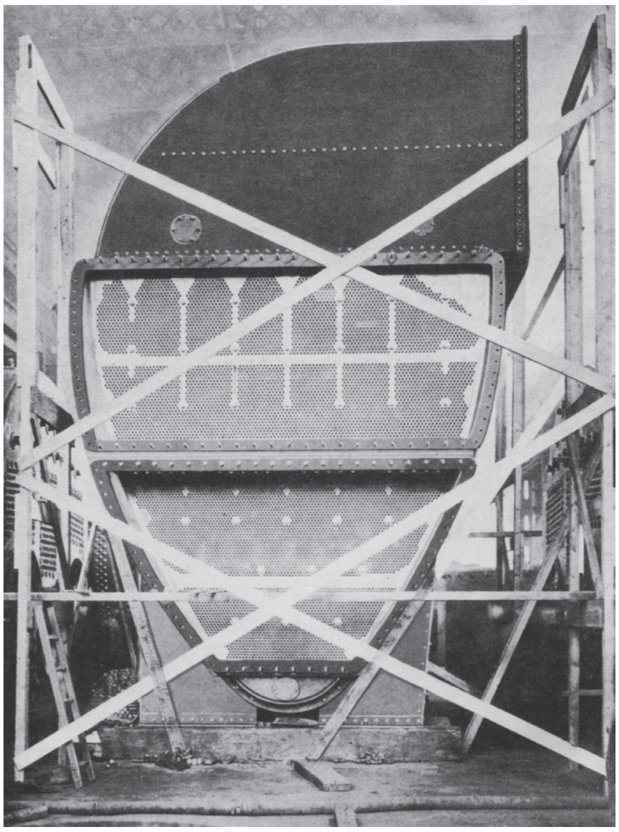


Fig. 15-69 **Main Condenser** – After end of *Olympic*'s port main condenser in the shops, shown here in the installed orientation, with the casing partly removed. *(*The Shipbuilder*/Authors' collection)*

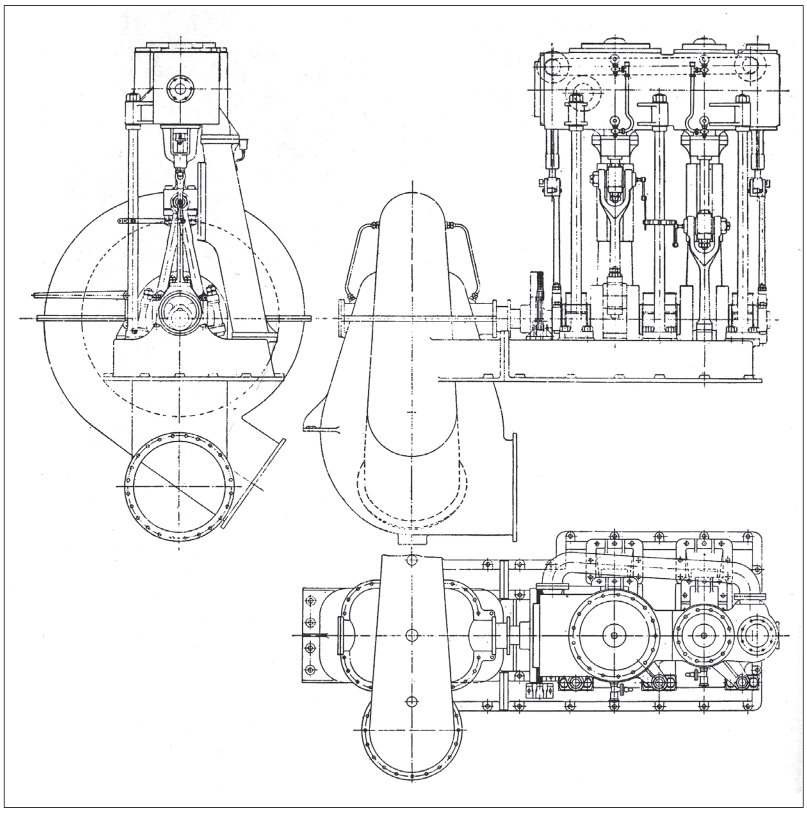
casing, the after end of which was solidly bolted to the turbine engine seats. The connection between the turbine casing and thrust block was achieved by a set of threaded stay rods parallel to the shaft; these ran through bossings in the sides of the thrust and main bearing blocks, each rod being provided with a set of adjusting and jamb nuts at each end. Additionally, the stay rods were used to maintain the fore-and-aft positioning of the thrust block relative to the turbine casing, which in turn maintained proper clearance between the moving blades of the rotor and the stationary blades within the casing. It will be noted that this thrust block is a bit smaller in all respects when compared to the thrust blocks of the wing shafts; this is because in direct-drive turbines, the pressure of incoming steam pressing aft against the blades and the end surface of the rotor helped to somewhat balance the forward thrust of the propeller and shaft.

The turbine casing was of cast iron. The casing was ribbed both circumferentially and longitudinally. The views presented in Figures 15-45 through 15-51 show parts of these casings, while Figures 15-43 and 15-44 show some of the immense wood patterns used in creating the molds in which the various parts were cast.

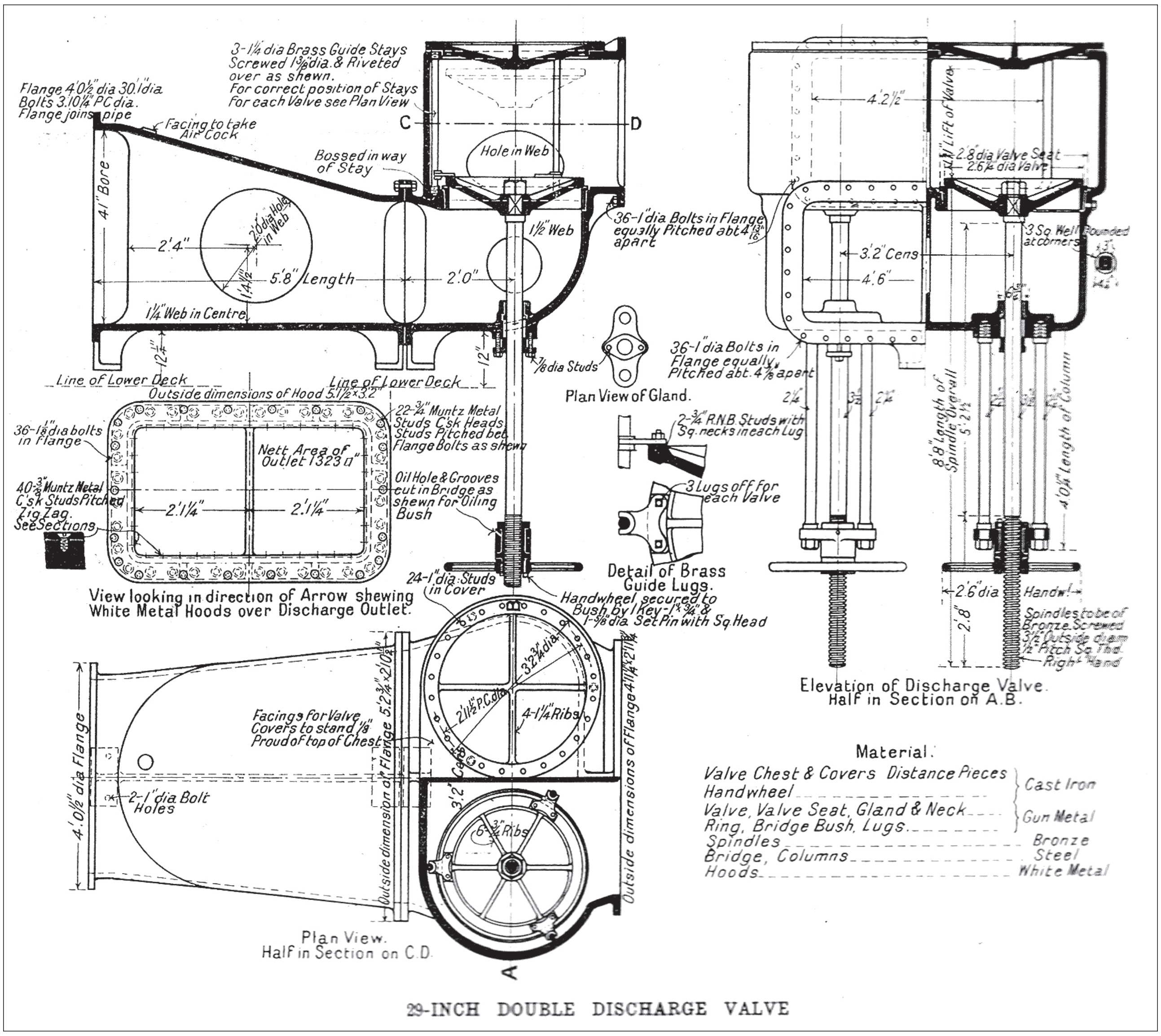
The blades varied in length from 18in to 25½in, and were built up on the segmented or 'rosary' system, laced on wire through the blades and distance-pieces at the roots, and with bindings soldered on the edges. The whole area of the turbine rotor at the forward end was utilized to balance the thrust of the propeller, so that there was no dummy piston fitted. Within the spindle glands there were fitted twenty rows of radial rings and four Ramsbottom rings. The bearings, which had water circulation and forced lubrication, were exceptionally large, being 3ft x 6ft 9½in at both ends.

The forced-lubrication system which supplied the turbine rotor bearings with oil was located in the Turbine Engine Room. In addition to the turbine rotor bearings, this system also supplied lubrication to all of the thrust blocks and shaft bearings. G. & J. Weir supplied the pumps for this system. Three pumps were fitted, one

Right Fig. 15-70 **One of the Main Circulating Pumps** – This drawing illustrates both the starboard forward and port after pump sets; the remaining two sets were identical except they were 'mirrored' through a transverse plane. *(*The Shipbuilder*/Authors' collection)*



Below Fig. 15-71 **29in Double Discharge Valve** – One of these double valve assemblies was located immediately inboard at each of the two large rectangular condenser circulating water discharge openings located at the forward end of the Turbine Engine Room at the level of the load waterline. *(*The Engineer*/Authors' collection)*


3-1¼ dia Brass Guide Stays Screwed 1⅜dia.& Riveted over as shewn.
For correct position of Stays for each Valve see Plan View
Flange 4'0½" dia 30.1'dia. Bolts 3.10¼" P.C dia.
Flange joins pipe
Facing to take Air Cock
C
D
Bossed in way of Stay
Hole in Web
41" Bore
2'0"dia Hole in Web
2'.4"
1'.4½"
5'.8" Length
2'.0"
1½" Web
36-1"dia Bolts in Flange equally Pitched abt 4 13/16" apart
1¼" Web in Centre
12¼"
12"
⅞ dia Studs
Plan View of Gland.
Line of Lower Deck
Line of Lower Deck
Outside dimensions of Hood 5.1½"×3.2"
36-1⅛"dia bolts in Flange
22-¾" Muntz Metal Studs C'sk Heads Studs Pitched bet Flange Bolts as shewn
Nett Area of Outlet 1323 □"
40-⅜" Muntz Metal C'sk Studs Pitched Zig Zag. See Sections
2'.1¼"
2'.1¼"
Oil Hole & Grooves cut in Bridge as shewn for Oiling Bush
View looking in direction of Arrow shewing White Metal Hoods over Discharge Outlet.
24-1"dia Studs in Cover
Handwheel secured to Bush by 1 Key-1"×¾" & 1-⅝"dia. Set Pin with Sq Head
2-¾" R.N.B. Studs with Sq. necks in each Lug
3 Lugs off for each Valve
Detail of Brass Guide Lugs.
4'.2½"
1.1" Lift of Valve
2.8 dia Valve Seat
2.6¼ dia Valve
3 Sq. Well Rounded at corners
3'.2" Cens
4'.6"
36-1"dia Bolts in Flange equally Pitched abt. 4⅞ apart
2¼
3½
2¼
8'.8" Length of Spindle Overall
5'.2½
4'.0¼" Length of Column
2'.6"dia Handw!
2'.8"
Spindles to be of Bronze Screwed 3½" Outside diam ½" Pitch Sq. Thd. Right Hand
Elevation of Discharge Valve. Half in Section on A.B.
3'.2¾"dia
2'.11½" P.C.dia
4-1¼" Ribs
Facings for Valve Covers to stand ⅛" Proud of top of Chest
Outside dimension of Flange 5.2¾"×2.10½"
Outside dimensions of Flange 4.11¼"×2.11¼"
4'.0½" dia Flange
2-1"dia Bolt Holes
3'.2" Cens
6-¾" Ribs
A
Plan View. Half in Section on C.D.
Material.
Valve Chest & Covers Distance Pieces
Handwheel
Cast Iron
Valve, Valve Seat, Gland & Neck
Ring, Bridge Bush, Lugs.
Gun Metal
Spindles — Bronze
Bridge, Columns — Steel
Hoods — White Metal
29-INCH DOUBLE DISCHARGE VALVE

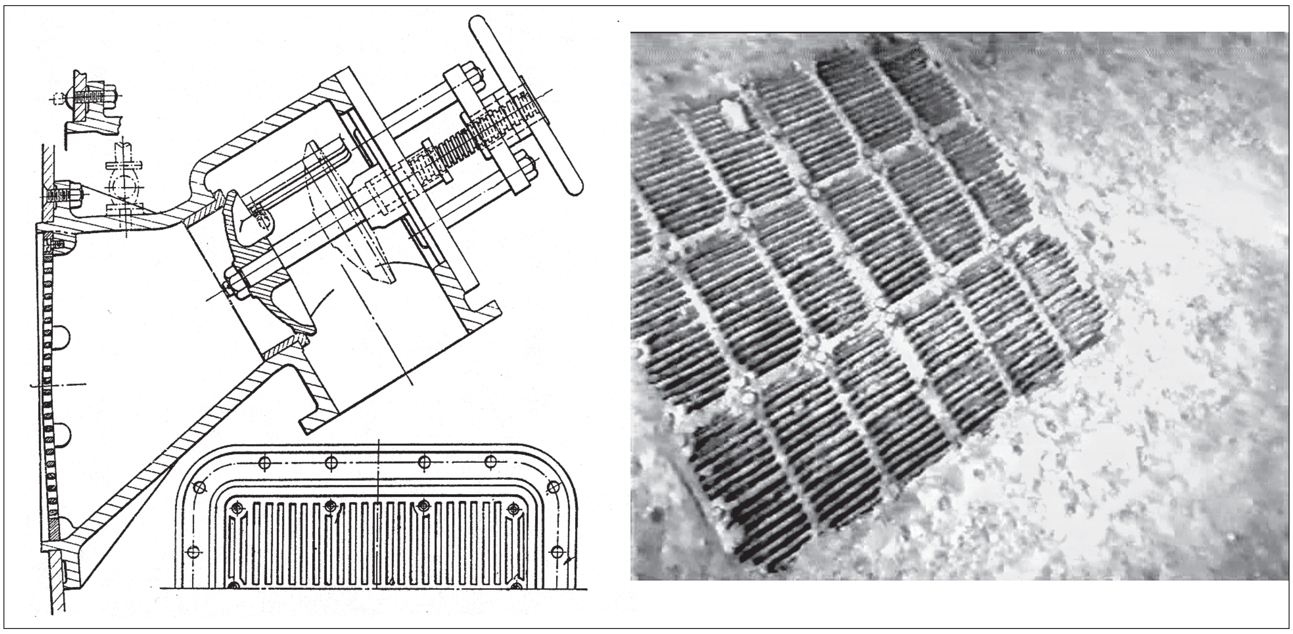


Fig. 15-72 **H&W-Design Main Injection Valve** – Though of smaller proportions than the similar valves employed in *Titanic*, the basic design details are identical. A rectangular section inlet branch transitions into the circular opening of the inlet valve, this being the easiest way to obtain the required area through the brass strainer, or 'strum', which guards the inlet. The small cock shown in phantom at the top of the inlet branch is connected to a ¾in high-pressure steam line. This was commonly called the 'ice connection', and was used for thawing accumulated ice or for clearing the accumulation of weeds, debris and marine growth from the strum. All main through-hull openings were similarly fitted.

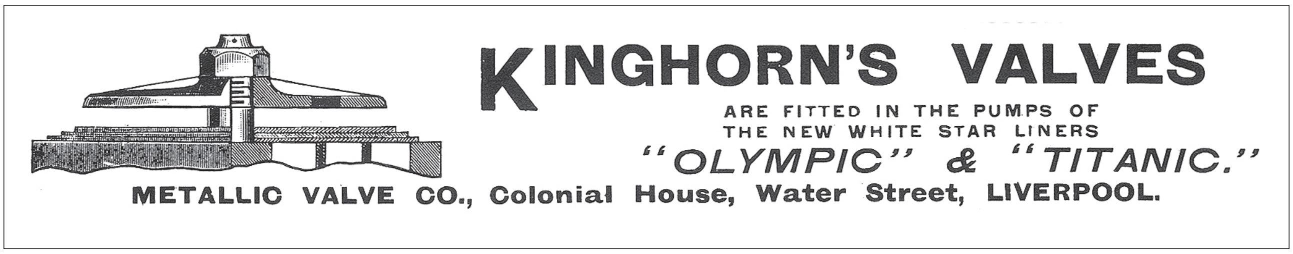
being allocated to the turbine rotor bearings and thrust block, one to the reciprocating engine thrust blocks and all of the shaft bearings, and the third pump acting as a stand-by. The pumps were of the vertical single-cylinder double-acting type with a steam cylinder and pump barrel, both 8in in diameter, and having a stroke of 15in. The hourly capacity of each pump was 6,000 gallons at twenty double strokes per minute. The pumps drew their supply from the collection tanks into which the spent oil from the various bearings drained. From the pumps, the oil was forced first through filters to remove dirt and impurities. From the filters, the oil passed through two oil coolers which were supplied with their own circulating water pump. From the coolers, the oil was discharged to the supply tanks located high up in the Turbine Engine Room casing at the level of the Shelter Deck (C), with gravity providing the actual pressure to the bearings at a head of 20psi.

As with the reciprocating engines, the turbine was also fitted with turning gear, the principal difference being the mode of power. Whereas the power-operated turning gear for the reciprocating engines was steam-driven, the turning gear fitted to the turbine was driven by a 15BHP electric motor. The turning gear for the turbine served much the same purpose as did the machinery fitted to the reciprocating engines.

Power-operated lifting gear was supplied to aid in the removal of the upper half of the turbine case to facilitate inspection and repairs of the blading and rotor. This equipment was operated by a 30BHP electric motor.

Maneuvering gear

The control of *Titanic*'s propelling machinery at sea and during maneuvering was accomplished by means



KINGHORN'S VALVES

ARE FITTED IN THE PUMPS OF
THE NEW WHITE STAR LINERS
"OLYMPIC" & "TITANIC."

METALLIC VALVE CO., Colonial House, Water Street, LIVERPOOL.

Fig. 15-73 **Kinghorn Valves** – Advertisement from the Metallic Valve Co., the maker of Kinghorn valves, which were used in most, if not all, of the positive-displacement pumps throughout the ship. *(*The Shipbuilder*/Authors' collection)*

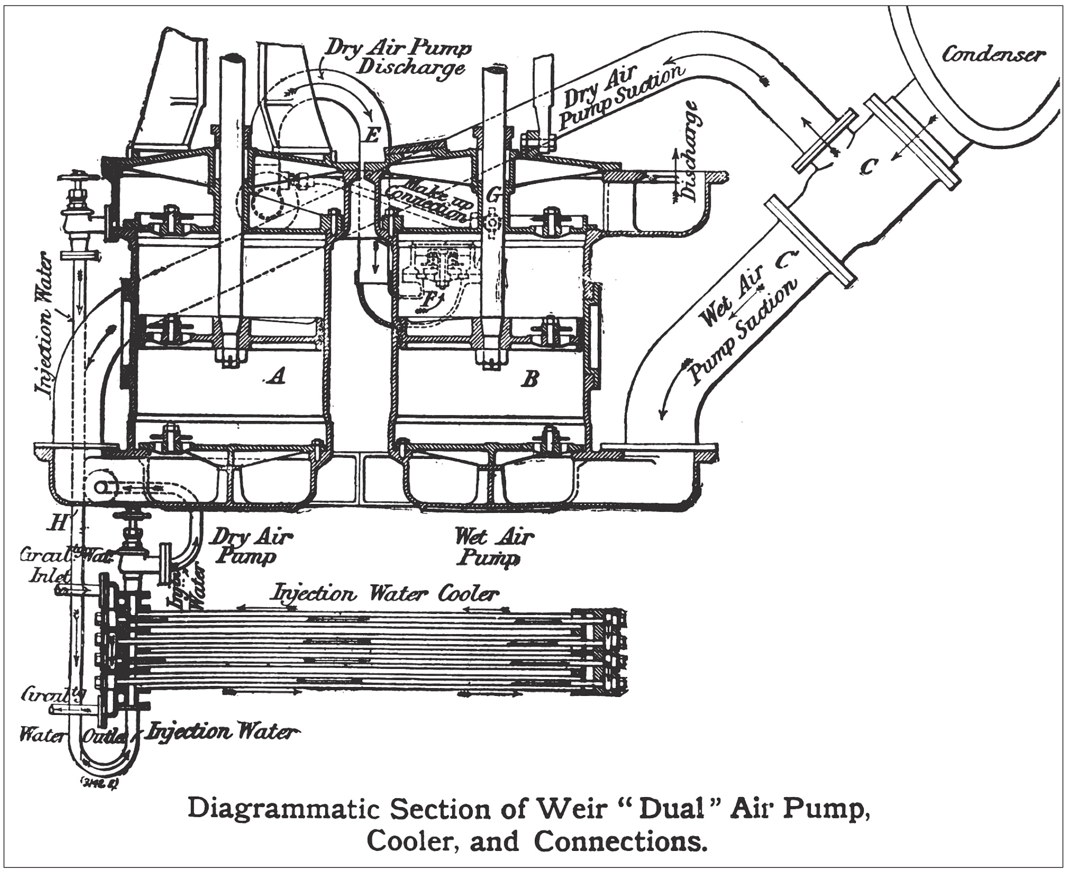


Fig. 15-74 **Diagrammatic Representation of Weir 'Dual' Air Pump** – Pump A, the 'wet' pump, is situated below the steam cylinder; pump B; the 'dry' pump, is driven by beam and links from the piston rod at pump A. One connection, C, is made to the condenser for each dual pump set; a branch pipe for vapor is led to the dry pump and all water is passed by C' to the wet pump. The dry pump discharges through return pipe E through spring-loaded valve F into the wet pump at a point below its head valves. Injection water is supplied to the dry pump for water sealing, clearance filling, cooling, and vapor condensing. During start-up, the filling valve G is opened momentarily to enable the vacuum to draw in water from the hotwell of the wet pump. Once in operation, valve G is then closed, and the water passes from the hotwell of the dry pump by the pipe H to the pump injection cooler and back to the dry pump in a continuous closed circuit, with any excess passing over pipe E to the wet pump. The spring-loaded valve F is adjusted to maintain about 20in. of vacuum in the dry-pump hotwell when the condenser is working at 28in. vacuum. This 8in difference of pressure is sufficient to cause the water to overcome the cooler friction and pass into the suction, at the same time never allowing a direct air connection. *(Scott Andrews collection)*

common to nearly all steamships of the period. The two notable exceptions to this were the additional equipment and controls required for operating the exhaust steam turbine and certain changes made necessary to the gear of the reciprocating engines owing to the enormous size of these units.

The two steam leads from the boilers were connected at the bulkhead stop-valves by two shut-off valves, so that either lead could be utilized for supplying steam to either engine. As previously stated, steam was admitted to each reciprocating engine via a main steam stop valve fitted to the inboard side of the valve chest of each high-pressure cylinder. The main stop-valves were of the equilibrium double-beat type, operated by hand wheels port and starboard from the center of the Engine Room Platform.

Attached to the side of each main stop valve was a smaller bypass valve, which also was operated from the center of the Engine Room Platform by a separate set of hand wheels. The bypass valves were used for controlling the engine revolutions at low speeds during maneuvering, the object being that the smaller valve could be opened and closed much more quickly, and revolutions much more accurately adjusted at low speeds than with the main valves. The main valves were used for controlling revolutions at sea, the large size of these valves being necessary for supplying the immense volumes of steam required when running at steady speeds at full power. Incorporated within the casing of each stop valve, at the point where each valve assembly was attached to the inlet of each high-pressure valve chest, was a throttle plate of the disc type mounted on a horizontally rotating shaft. This shaft was operated by a steam throttle valve engine having a 9in bore by 12in stroke and working on 215psi; the throttle engine was in turn regulated by an Aspinall inertia-type governor mounted to a lever driven by links from the crosshead of the high-pressure

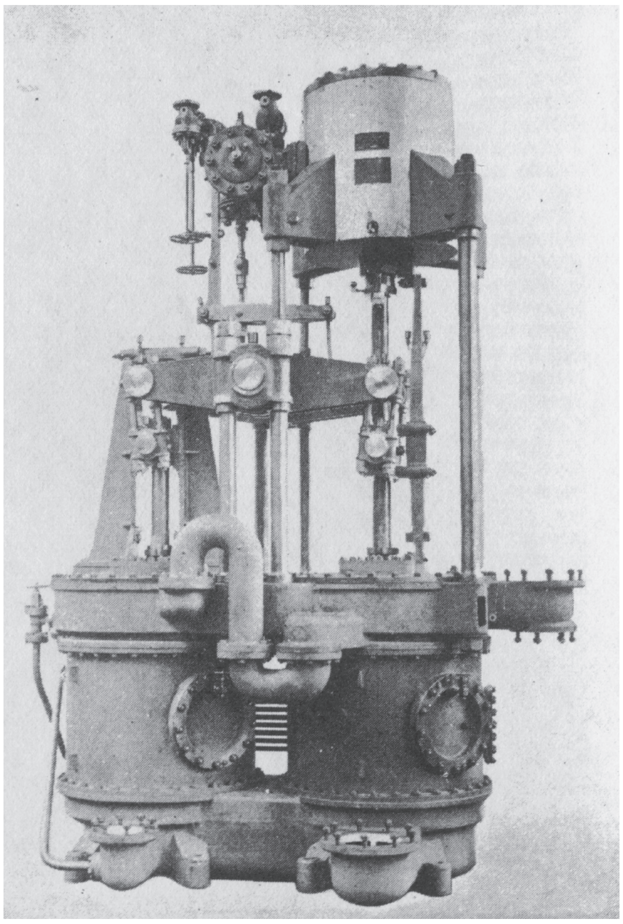


Fig. 15-75 **Weir 'Dual' Twin Air Pump** – One of the four sets of dual twin air pumps; the starboard forward set is pictured here. *(*The Shipbuilder*/Authors' collection)*

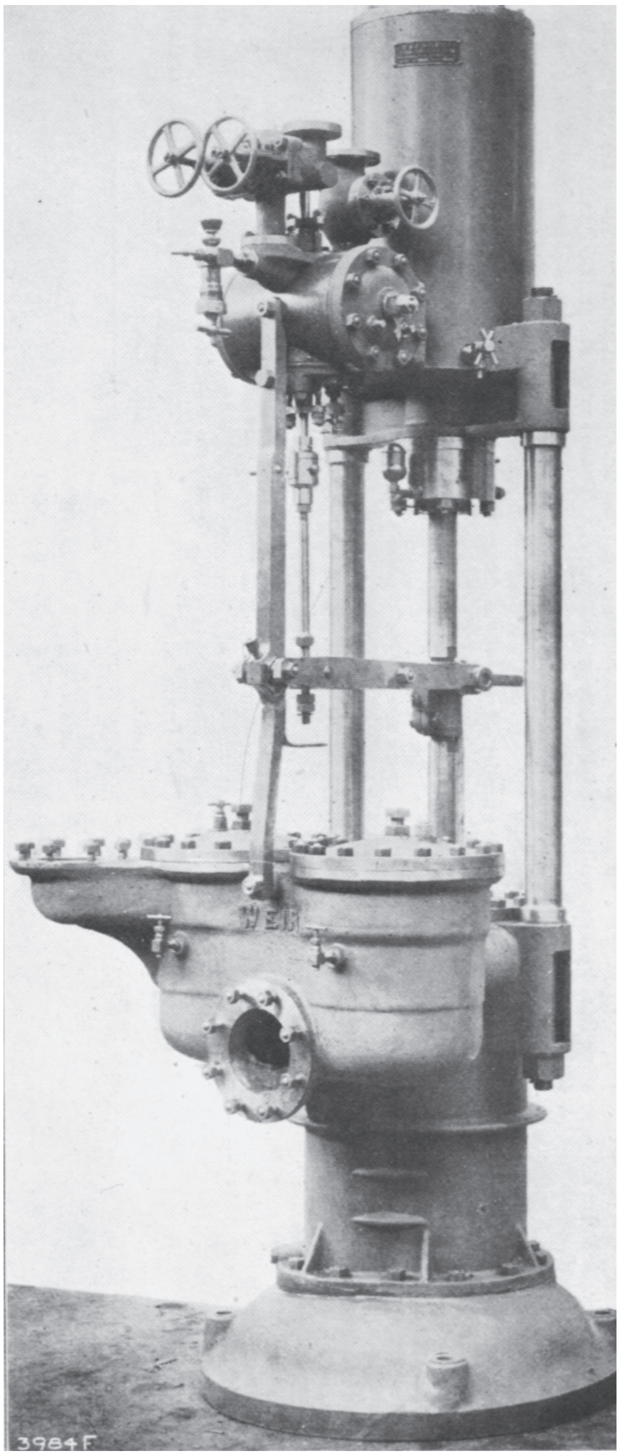


Fig. 15-76 **Weir Hotwell Pump** – A typical Weir vertical simplex direct-acting pump used for the hotwells. This example is from the *Aquitania. (*Engineering*/Authors' collection)*

cylinder. Figures 15-57 to 15-59 illustrate an Aspinall governor and describes its operation.

Reversing was accomplished by a Brown's steam-hydraulic engine. This engine was similar in type and operation to those employed on other steamers of the period, although of much greater size. The steam cylinder was 27in in diameter with a stroke length of 36in. Each reversing engine was controlled by a lever attached to its side and located immediately beside the hand wheels for the main stop and bypass valves. The lever operated a balanced double-ported slide valve, admitting steam to either side of the piston of the cylinder located at the bottom of the engine. The piston in the steam cylinder was mounted on a piston rod that passed up through the hydraulic cylinder and connected to a lever on the wyper shaft. Also mounted to this piston rod was the piston of the hydraulic cylinder. The hydraulic cylinder served to control without shock the motion being transmitted to the wyper shaft. In normal operation, movement of the reversing lever produced an immediate proportional response of the piston rod. In smaller installations, a large hand wheel was usually provided, which could be used to manually effect reversing through a worm-driven rack-and-pinion arrangement. This was done to provide both a means of moving the gear during setting of the valve gear in port and as an emergency override in case of failure of the steam cylinder while at sea. However, the size of the valve gear on *Titanic* made manual operation impractical, so no hand wheels were fitted. Instead, a Brown Brothers steam hydraulic pump was fitted as a back-up power source for both the reversing engines and the Brown's engine that operated the turbine engine change-over valves. This pump charged hydraulic pressure

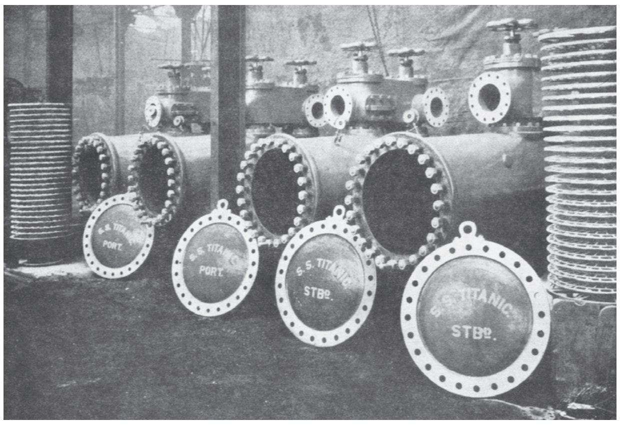


Fig. 15-77 **Main Feed Filters of *Titanic*.** *(*The Shipbuilder/*Authors' collection)*

accumulators to supply fluid under pressure directly to the hydraulic cylinder of each Brown's engine. The steam cylinders of this pump were 10in in diameter with a stroke of 7in, while the two hydraulic rams were of 5in and 3½in diameters.

The spent steam from the valve chests of the low-pressure cylinders of each set of reciprocating engines was exhausted into a pair of 61in-diameter pipes. These were fabricated by Thomas Piggott & Co. Ltd of Birmingham. They were of steel, lap-welded, with a strap riveted over the weld, and were provided with bellows joints between each rigid connection to allow for expansion without endangering the airtight integrity of the pipes leading to the condensers. These joints consisted of two thin steel discs that were riveted together at their periphery through a steel ring. They were about 2ft 6in larger in diameter than the pipes to which they were connected by flanges. The slightly conical form of the disc plates compensated for any difference in length due to expansion or contraction. Similar expansion joints were incorporated into all pipes connected with the condensers, including the eduction pipes from the turbine.

The exhaust pipes directed the steam into a pair of huge change-over valves. These valves were situated one on each side of the center of the Turbine Engine Room just abaft the forward bulkhead. The valves were of the piston type with a ring of special form. When the pistons were at their highest position, steam was directed downward through a strainer below each valve to the turbine; when lowered, the ports were open to the condensers and the supply of steam to the turbine was cut off. A lever, the opposite end of which was connected to a single Brown's engine of the type used for reversing the reciprocating engines, operated the piston of each valve. Control of the change valves was accomplished by means of a hand lever located on the port side of the engine platform, immediately to the left of the hand wheels for the stop and by-pass valves, and just above the main reversing lever of the port reciprocating engine. The change-valve engine was also controlled by the turbine governor gear which was set to cut off the steam to the turbine by means of a Proell centrifugal governor if the revolutions exceeded the normal rate by 20 per cent. The hydraulic engine then caused the pistons of the change valves to fall, redirecting the flow of exhaust steam directly into the condensers. The arrangement may be better understood by referring to Figures 15-1 and 15-2 and the section through the Turbine Engine Room given in Fig. 3, from which it will be seen that the major parts were in duplicate with an exhaust pipe, change-over valve and steam admission to the turbine and a main condenser on each side of the centerline of the ship.

The eduction pipes from the turbine to the condensers, one located on each side of the upper half of the case, were each fitted with a large sluice valve as shown in Fig. 15-65. Details of these valves are reproduced in Fig. 15-66. The sluice valves enabled either of the condensers connected to the turbine and both reciprocating engines to be shut off for repairs, the steam passing then to one condenser. The most

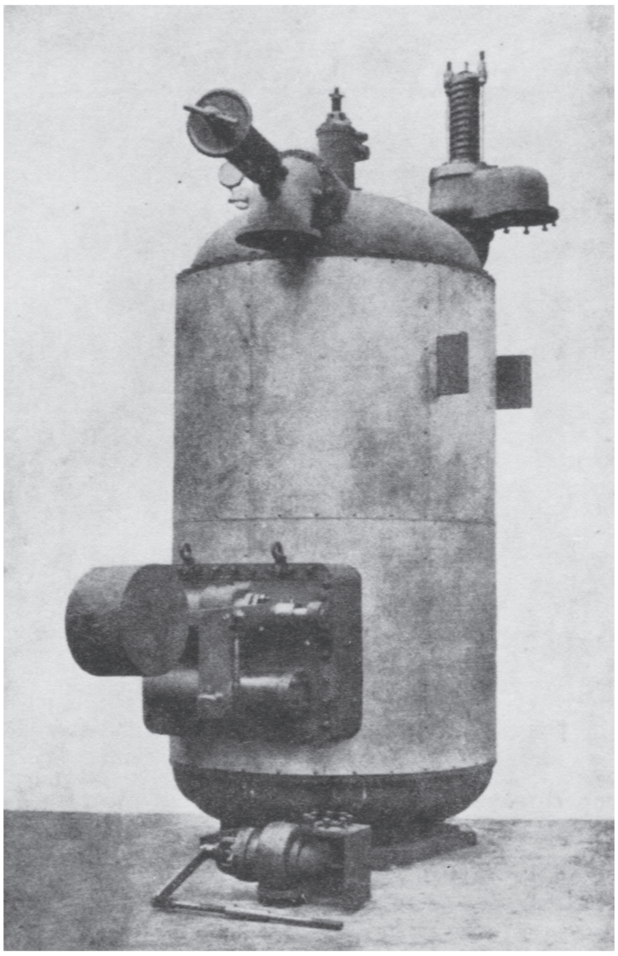


Fig. 15-78 **Direct-Contact Heater**. *(*The Shipbuilder/*Authors' collection)*

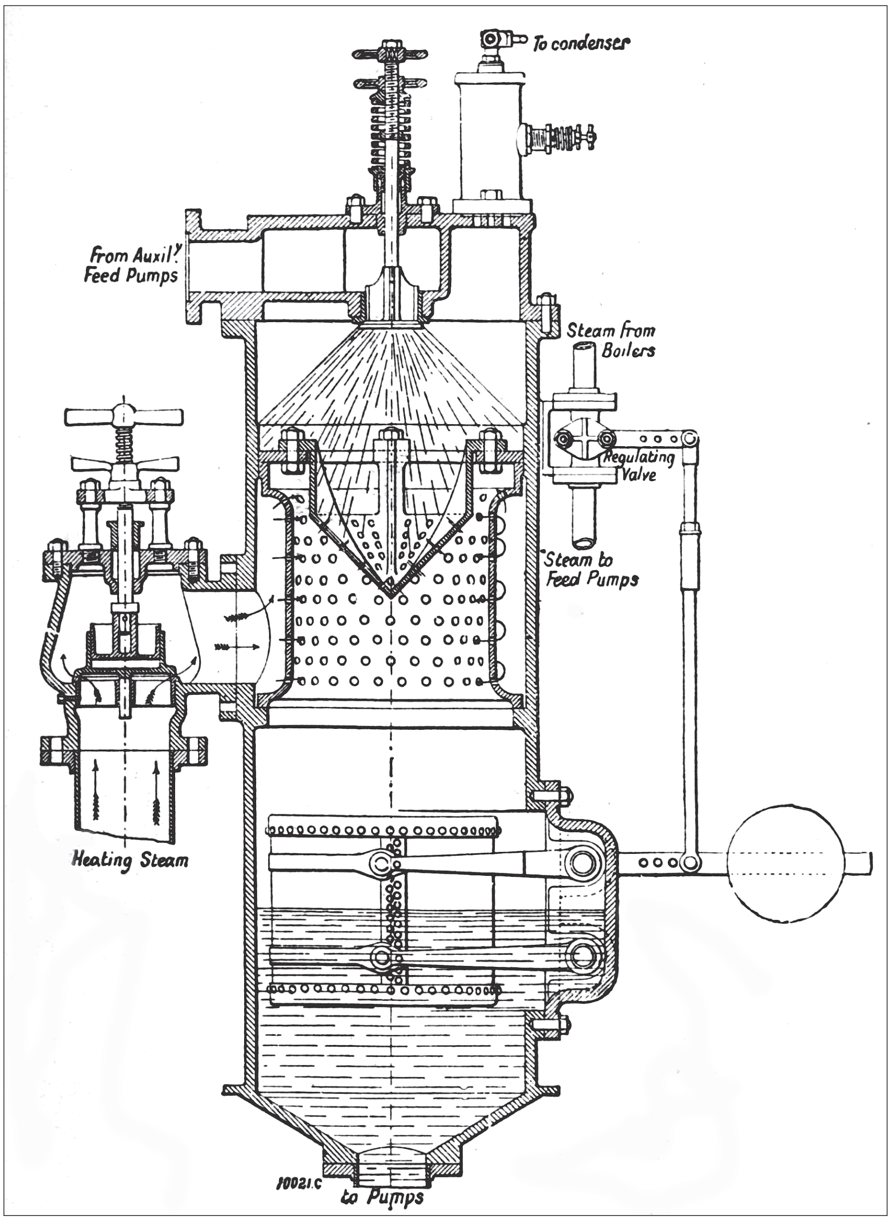


Fig. 15-79 **Weir Direct-Contact Heater** – Principal Parts. *(Scott Andrews collection)*

unusual feature of these valves was their enormous size. The total length was 19ft 1in and the breadth 11ft 9½in. The opening was 8ft 6in x 10ft 6in, but the clear area was somewhat less than these multiplied together owing to the presence of the stiffening stays and valve supports. The gate of each valve was in two parts owing to its great size. On the back of each gate were two racks which engaged pinions mounted on a cross shaft having worm wheels, which in turn engaged the spur gear that was rotated by a 5BHP electric motor. The sluices were built up of a cast-steel body formed in sections. Rather than subcontracting these parts to an outside firm, Harland & Wolff constructed these massive valves themselves at their Belfast works.

Condensers and return-feed plant

The condensing plant was designed to operate at about 28 to 28½in vacuum at a barometric pressure of 30in Hg and a circulating water temperature of 55° to 60°F. The two main condensers were fitted on opposite sides of the exhaust turbine. The partially completed starboard main condenser of the *Britannic*, identical to those fitted aboard *Titanic*, is shown in Fig. 15-67. In this view the condenser is on its side. The two inlets for the circulating water which were on the bottom of the condenser are seen to the left of the illustration, along with the plates which formed the footing or stool on which the condenser sat; in between these plates may be seen the two condensate draw-off connections to the air pumps. The large rectangular inlet from the turbine exhaust is to the top of the view, but would be to the left with the condenser upright and connected to the turbine. In Fig. 15-68 a view of the

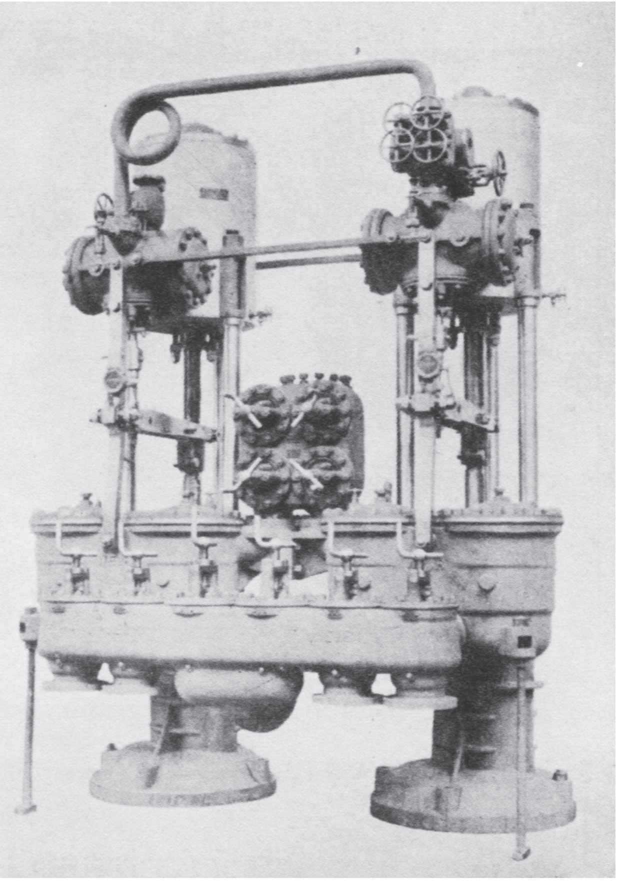


Fig. 15-80 **One Pair of Vertical Direct-Acting Feed Pumps**. (The Shipbuilder/*Authors' collection)*

forward end of the port main condenser, the oblong opening was the exhaust steam inlet connection direct from the reciprocating engine through the change valve, used when operating with the turbine cut-out. The large round opening in the lower right corner of the picture was the circulating water discharge outlet.

The condensers were pear-shaped in form, a practice adopted early on by the marine engineers at Harland & Wolff, as this form was found to provide superior performance to earlier condensers of cylindrical or oblong section. In line with the main inlet, from the turbine extending the whole length of the condenser, division plates were fitted both to stiffen the structure internally and to ensure a uniform distribution of the incoming steam. The pear shape of the section served to increase the tube area where the largest volume of steam was admitted. The tubes were of ¾in external diameter and the pitch varied from $1^3/_{16}$in upwards. The total surface in the two condensers was about 50,000 sq.ft. There was also an auxiliary condenser located on the starboard side of the Reciprocating Engine Room for dealing with the exhaust steam from all of the auxiliary engines, including those of the main generating sets, while the vessel was in port. This unit had about 3,600sq.ft of cooling surface. In the case of both the main and the auxiliary condensers, the shell was made of mild steel with the doors and frames of cast iron; the tube plates were of rolled brass and the tubes of solid drawn brass.

The main circulating pumps, four in all, were of Harland & Wolff's own manufacture. The main installation consisted of four centrifugal pumps, with two located on each side of the Turbine Engine Room for each main condenser. Each pump had a 29in inlet and discharge pipes, with each pump's inlet pipe connected to an individual sea chest and inlet valve. The pump housings and impellers were cast of gunmetal, a hard bronze composed of 90 per cent copper and 10 per cent tin. The impellers had a diameter of 5ft 3 in. A two-cylinder compound engine working on a pressure of 120PSIG and having cylinders of 13in and 22½in and a stroke of 15in drove each pump.

The cranks of these engines were placed at 180° respective to one another so as to reduce vibration to a minimum. In addition to the inlet connections at the sea chests, so-called 'bilge injection' was also provided for with these pumps. Valves and pipes were fitted to allow the forward circulating pumps to draw water from the bilges of the Reciprocating Engine Room, while the after pumps were arranged to draw water from the bilges of the Turbine Engine Room. (As a result of the loss of *Titanic*, connections that allowed these pumps to draw directly from the entire bilge piping system were designed into *Britannic* and retrofitted into *Olympic*. While not even these huge pumps could have prevented the eventual foundering of the ship, it was not lost on the designers that valuable time could be gained by their use in an emergency – time which might allow the complete evacuation of the vessel.) The auxiliary condenser circulating pump was also by Harland & Wolff. Again of the centrifugal type and having 12in inlet and discharge pipes, this pump was driven by a single-cylinder double-acting steam engine having a bore of 8in diameter and a stroke of 9in, working on a pressure of 120PSIG. Materials were the same as used in the main circulating pumps.

The four main air pumps were supplied by G. & J. Weir Ltd. These were of the 'Dual' type, handling 155,000lb of condensed steam per hour each and designed to maintain a vacuum of 28in when working at thirty double strokes per minute. They each had a steam cylinder 22in in diameter, pump barrels of 36in diameter, and a stroke of 21in. The pump barrels were of gunmetal, with cast-iron bases and tops, and were fitted with gunmetal buckets, manganese-bronze pump rods, steel piston rods, and Kinghorn valves in gunmetal seats.

The pumps worked on a steam pressure of 120PSIG, but the steam cylinders were designed to withstand the full boiler pressure of 215PSIG. The air pump for the auxiliary condenser was of the same type and of the same materials as the main air pumps, but of smaller dimensions. The

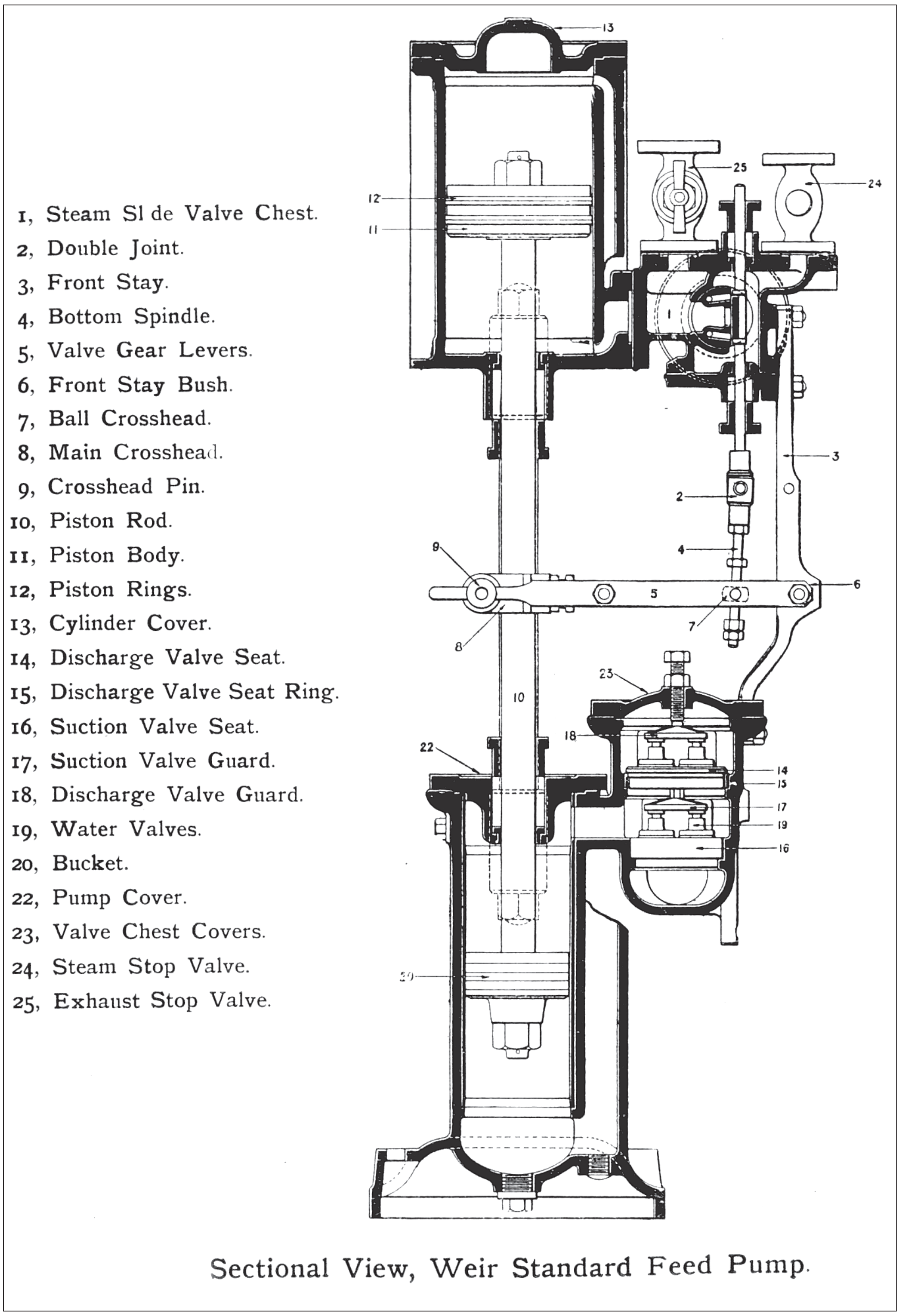
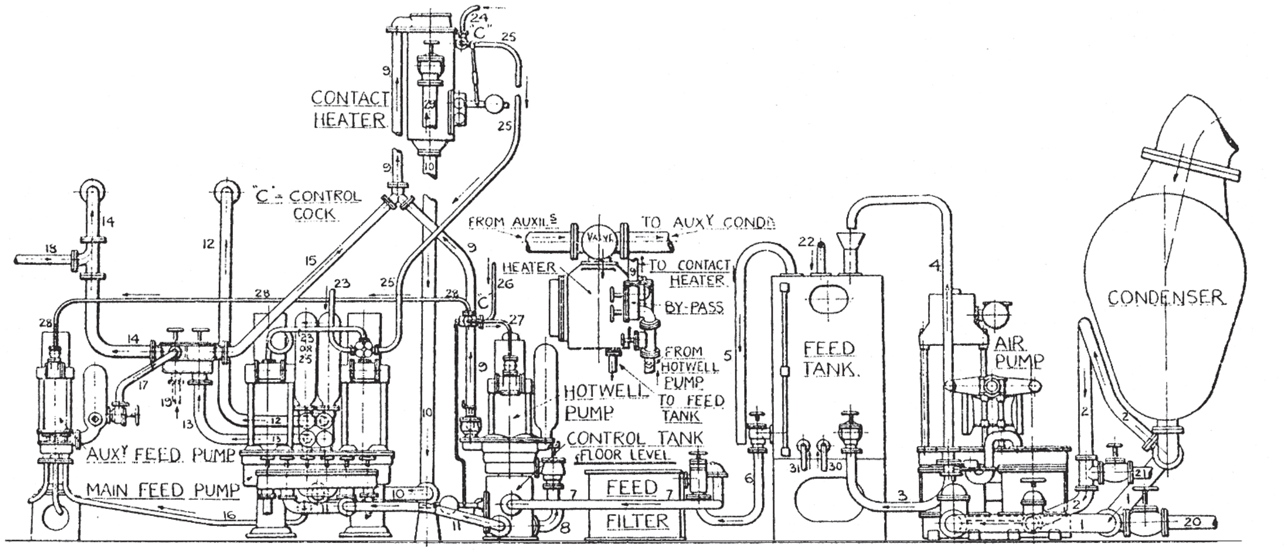

1, Steam Slide Valve Chest.
2, Double Joint.
3, Front Stay.
4, Bottom Spindle.
5, Valve Gear Levers.
6, Front Stay Bush.
7, Ball Crosshead.
8, Main Crosshead.
9, Crosshead Pin.
10, Piston Rod.
11, Piston Body.
12, Piston Rings.
13, Cylinder Cover.
14, Discharge Valve Seat.
15, Discharge Valve Seat Ring.
16, Suction Valve Seat.
17, Suction Valve Guard.
18, Discharge Valve Guard.
19, Water Valves.
20, Bucket.
22, Pump Cover.
23, Valve Chest Covers.
24, Steam Stop Valve.
25, Exhaust Stop Valve.
13
25
24
12
11
1
3
2
4
9
5
6
7
8
23
10
22
18
14
15
17
19
16
20
Sectional View, Weir Standard Feed Pump.

Fig. 15-81 **Main Feed Pump** – A sectional drawing illustrating the internal features of the main feed pumps. *(Scott Andrews collection)*

steam cylinder of this pump was 10in in diameter, the pump barrels 17in in diameter, and the stroke 15in.

The term 'air pump' is something of a misnomer as, in addition to removing the large quantity of vapor which forms in the condenser when water is formed from the incoming steam, these pumps removed the collected water as well. This is the reason for the enormous capacity of this type of pump. The depth of water lifted by an average air pump was only one half inch per stroke, the entire remaining length of the stroke being required solely for removing air and vapor. In an effort to reduce the amount of vapor and therefore the required size of the air pump, it was common practice at the time to pass more circulating water through the condenser tubes than was necessary to condense the incoming steam. This was a trade-off at best, since the increased usage of circulating water required a larger circulating pump than would have otherwise been necessary.

The dual air pump was designed to solve this problem. Two pump barrels were used, the purpose being to have one – the 'wet air' pump – deal with the water at the condensing temperature (approximately 100°F) while the other – the 'dry air' pump – took the air and vapor which was approximately 80°F. The dry air pump had


CONTACT HEATER
"C" = CONTROL COCK
"C"
FROM AUXIL.S
TO AUXY CONDS
VALVE
HEATER
TO CONTACT HEATER
BY-PASS
FROM HOTWELL PUMP TO FEED TANK
HOTWELL PUMP
CONTROL TANK
FLOOR LEVEL
FEED FILTER
FEED TANK
AIR PUMP
CONDENSER
AUXY FEED PUMP
MAIN FEED PUMP
23 OR 25

1. Main air-pump wet suction (two are desirable).
2. Main air-pump dry suction.
3. Main air-pump discharge to feed-tank.
4. Main air-pump air-pipe and overflow to feed tank.
5. Feed-tank overflow to bilge.
6. Feed water from feed tank to feed filter.
7. Feed water from feed filter to control tank.
8. Hot-well pump suction from control tank.
9. Hot-well pump discharge to heater.
10. Feed-pumps suction from heater.
11. Main feed-pumps suction from control tank.
12. Main feed-pumps discharge to boilers (main feed range).
13. Main feed-pumps discharge to chest (auxiliary feed range or heater).
14. Main feed-pumps discharge to boilers (auxiliary feed range).
15. Main feed-pumps discharge to contact heater.
16. Auxiliary feed-pump suction from control tank.
17. Auxiliary feed-pump discharge to boilers (auxiliary feed line).
18. General service pump discharge to boilers (auxiliary feed line).
19. Main engine feed-pumps (if any) discharge to chest.
20. Air-pumps wet suction cross connection port and starboard.
21. Air-pumps dry suction cross connection port and starboard.
22. Auxiliary air-pump discharge to feed tank.
23. High-pressure direct steam to main feed pumps.
24. High-pressure steam to control cock on heater.
25. High-pressure regulated steam from control cock to main feed pumps.
26. Steam to cock controlled by control tank.
27. Regulated steam to hot-well pump.
28. Regulated steam to auxiliary feed pump.
29. Exhaust from auxiliaries to heater.
30. Evaporator coils drain to feed tank.
31. Refrigerator feed-pump discharge to feed tank.

Fig. 15-82 **Basics of the H&W Boiler Return-Feed System** – Schematic diagram showing the H&W boiler return feed system. This illustration shows all of the basic components and their relationship to one another. Multiple instances of certain equipment such as the two condensers, four air pumps, two feed tanks, etc. have been eliminated to simplify the illustration for the sake of clarity. The one notable difference in this arrangement over that employed in the *Olympic*-class liners is the type of feed filtration employed. Here, a gravity filter is shown in line prior to the hotwell control tank where, on *Olympic* and *Titanic*, pressure feed filters received the feed-water after it was discharged from the hotwell pumps.

cold injection. The cold injection condensed the vapor and reduced the volume of the air by cooling it before the air entered the foot valves of the dry-air pump barrel. The cold injection was not returned with the feed-water, as this would have served to further lower the temperature of the feed-water being returned to the feed tanks. This system resulted in a substantial reduction in size and weight over earlier types of air pumps. Fig. 15-74 shows the general arrangement of a Weir's dual air pump, while Fig. 15-75 shows the outboard side of

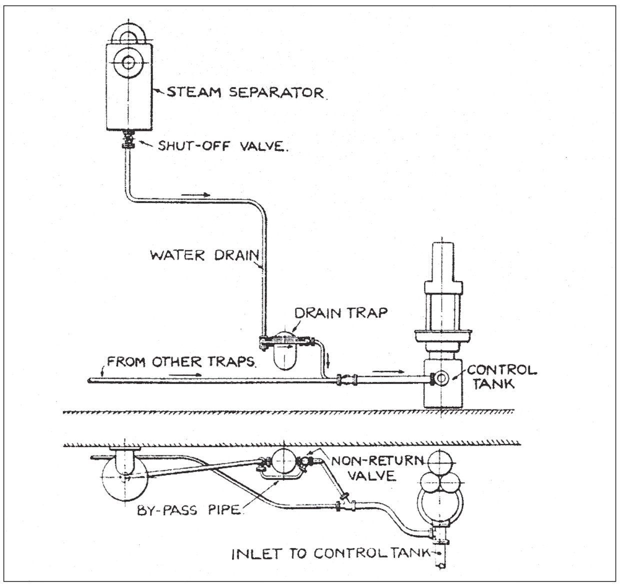

STEAM SEPARATOR
SHUT-OFF VALVE
WATER DRAIN
DRAIN TRAP
FROM OTHER TRAPS
CONTROL TANK
NON-RETURN VALVE
BY-PASS PIPE
INLET TO CONTROL TANK

Fig. 15-83 **Method of Recycling Condensate – Separators and Traps** – Diagram showing the system for recovering condensate collected from steam separators and steam traps within the engine rooms. Such water was reintroduced into the feed-water supply through the hotwell control tank.

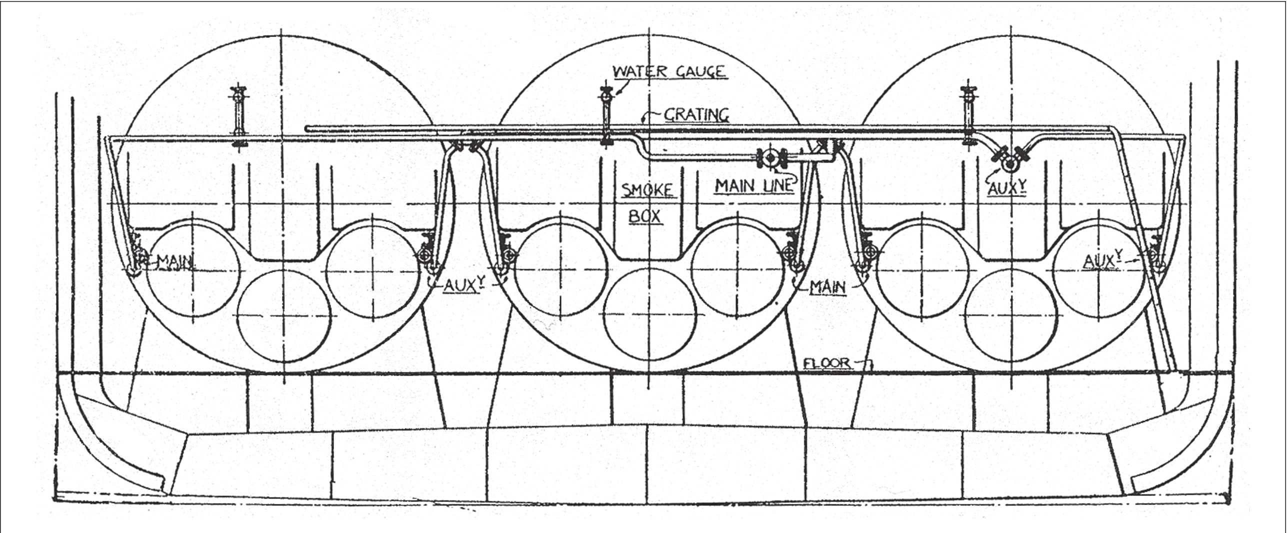

WATER GAUGE
GRATING
SMOKE BOX
MAIN LINE
AUX^Y
MAIN
AUX^Y
MAIN
AUX^Y
FLOOR

Fig. 15-84 **Typical Path of Main and Auxiliary Feed-water Connections at the Boilers** – Each feed pipe terminated at a combination feed and non-return valve. These pipes were led through the boiler rooms above the firing aisles at the height of the gauge-glass platforms. This kept them as low as possible above the deck plates while still keeping them out of the way of the firemen working the furnaces.

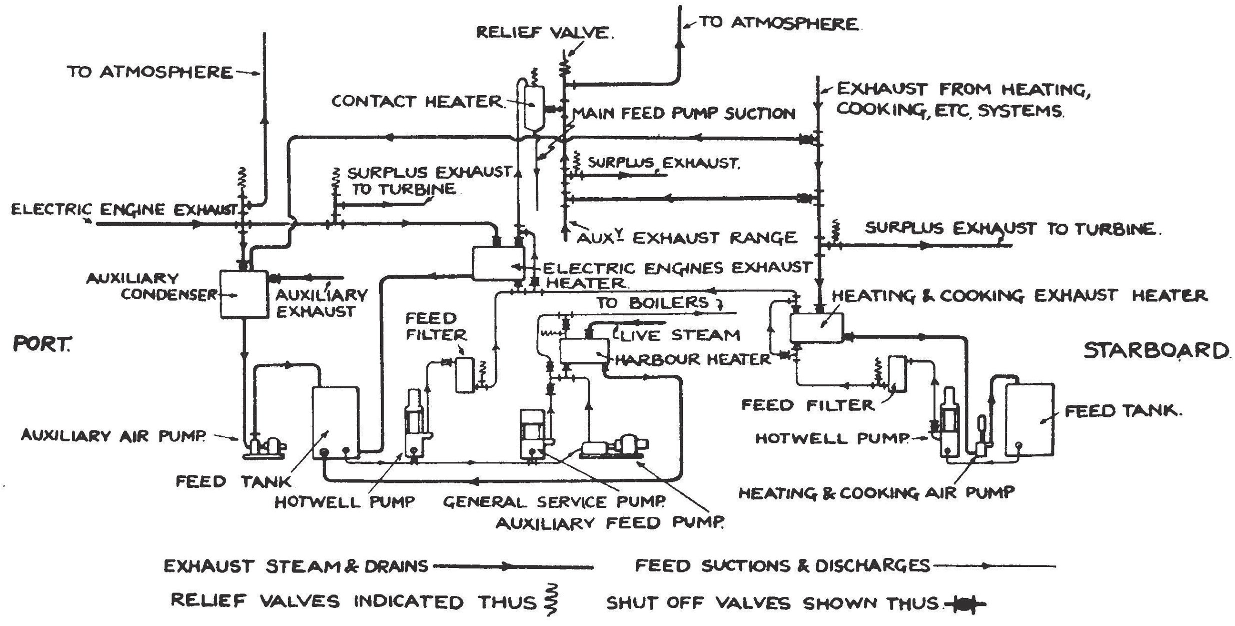
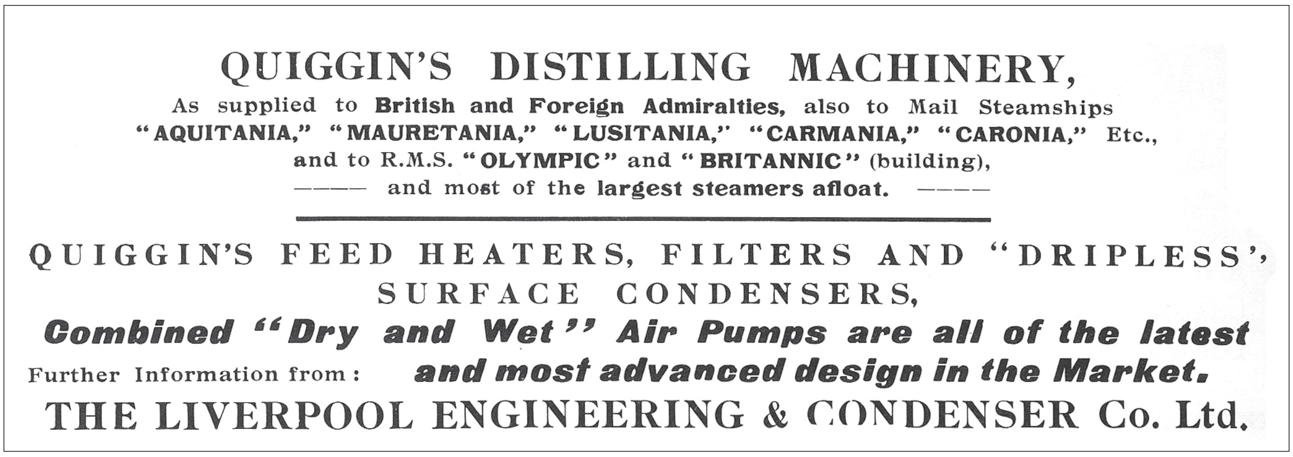

RELIEF VALVE.
TO ATMOSPHERE.
TO ATMOSPHERE
CONTACT HEATER.
MAIN FEED PUMP SUCTION
EXHAUST FROM HEATING, COOKING, ETC. SYSTEMS.
SURPLUS EXHAUST. TO TURBINE.
SURPLUS EXHAUST.
ELECTRIC ENGINE EXHAUST.
AUX^Y EXHAUST RANGE
SURPLUS EXHAUST TO TURBINE.
AUXILIARY CONDENSER
AUXILIARY EXHAUST
ELECTRIC ENGINES EXHAUST HEATER.
TO BOILERS
HEATING & COOKING EXHAUST HEATER
FEED FILTER
LIVE STEAM
HARBOUR HEATER
PORT.
STARBOARD.
FEED FILTER
FEED TANK.
HOTWELL PUMP.
AUXILIARY AIR PUMP.
FEED TANK
HOTWELL PUMP
GENERAL SERVICE PUMP.
AUXILIARY FEED PUMP.
HEATING & COOKING AIR PUMP
EXHAUST STEAM & DRAINS
FEED SUCTIONS & DISCHARGES
RELIEF VALVES INDICATED THUS
SHUT OFF VALVES SHOWN THUS

Fig. 15-85 **Main and Auxiliary Return Feed and Exhaust Heat Recovery System** – Schematic diagram showing the main and auxiliary return feed and exhaust heat recovery system employed in the *Olympic*-class liners. The heavy lines indicate exhaust steam and drain piping, while the lighter lines indicate piping carrying return feed-water from the main or auxiliary condensers.

the forward starboard pump set. The wet-air pump was placed below and driven directly by the steam cylinder, as this pump had the greatest load. The dry-air pump was driven by a beam and links.

The main air pumps discharged the condensate removed from the condensers into two feed tanks, one placed on each side of the ship just abaft the bulkhead dividing the engine rooms. Each feed tank had a capacity of 2,790 gallons. From the feed tanks, the water drained into two Weir control tanks, one on each side of the Reciprocating Engine Room. The control tanks measured 4ft x 4ft, with a depth of 3ft. The water was drawn from the control tanks by four Weir single-cylinder, vertical direct-acting hotwell pumps.



QUIGGIN'S DISTILLING MACHINERY,
As supplied to **British and Foreign Admiralties,** also to Mail Steamships
"AQUITANIA," "MAURETANIA," "LUSITANIA," "CARMANIA," "CARONIA," Etc.,
and to R.M.S. **"OLYMPIC"** and **"BRITANNIC"** (building),
—— and most of the **largest steamers afloat.** ——

QUIGGIN'S FEED HEATERS, FILTERS AND "DRIPLESS" SURFACE CONDENSERS,
Combined "Dry and Wet" Air Pumps are all of the latest and most advanced design in the Market.
Further Information from :
THE LIVERPOOL ENGINEERING & CONDENSER Co. Ltd.

Fig. 15-86 **Advertisement for Quiggin's Distilling Machinery**. (The Shipbuilder*/Authors' collection)*

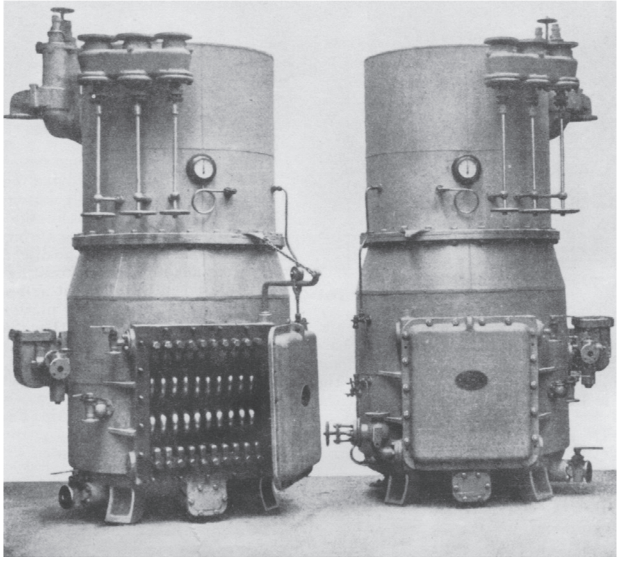


Fig. 15-87 **Two of the Evaporators**. (The Shipbuilder*/Authors' collection)*

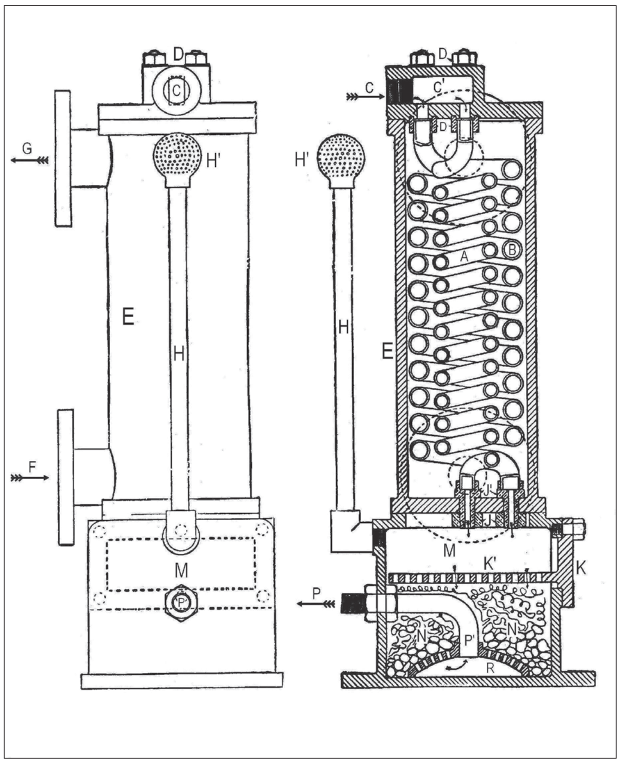


Fig. 15-89 **Fresh-Water Distiller.** *(Scott Andrews collection)*
A – Small-diameter steam coil
B – Large-diameter steam coil
C – Steam Inlet from evaporators
D – Nuts connecting top of coils to casing
E – Distiller casing
F – Circulating water inlet
G – Circulating water outlet
H – Air pipe
H' – Air inlet strainer
J – Nuts connecting bottom of coils to casing
J' – Coil ends (bottom)
K and K' – Access door and rose plate (combined)
M – Filter casing
N – Charcoal and gravel filtering media
P – Freshwater outlet
P' – Freshwater pipe
R – Rose on end of freshwater pipe

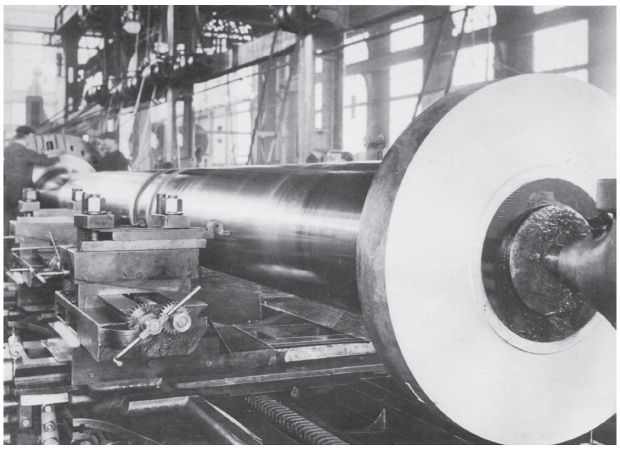


Fig. 15-88 **Shaft in Lathe** – A segment of one of *Britannic*'s propeller shafts in the lathe. *(H&W/Authors' collection)*

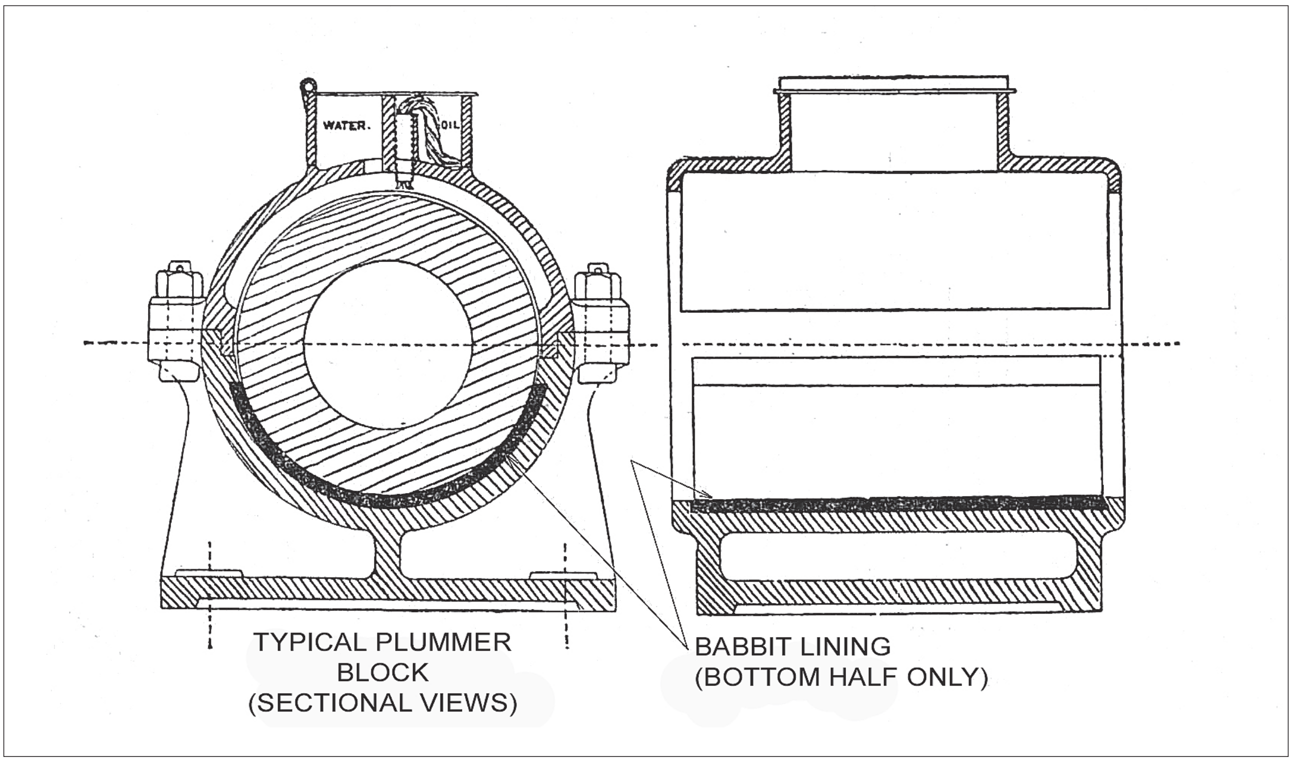

WATER.
OIL
TYPICAL PLUMMER BLOCK (SECTIONAL VIEWS)
BABBIT LINING (BOTTOM HALF ONLY)

Fig. 15-90 **Plummer Block** – A typical shaft bearing, or 'plummer block' of the type used to carry the shafts on *Titanic. (Scott Andrews collection)*

Each of these had a pump barrel 14in in diameter, a steam cylinder of 14in diameter and a stroke of 24in. The hotwell pumps were located in pairs on each side of the ship immediately adjacent to the control tanks. Each pair was capable of dealing with the whole of the feed-water, i.e., 700,000lb per hour; but under ordinary conditions all four pumps were operated together at slow speed.

From the hotwell pumps, the feed-water was discharged through the main feed filters. These filters, of which there were four, had a grid area of 17,000sq.in and a cloth area of 34,000sq.in each, for a total filtering area of 1,417sq.ft. They were supplied by Railton, Campbell and Crawford. They were placed against the forward bulkhead of the Reciprocating Engine Room, two on each side of the ship. The purpose of the main feed filters was to remove grease, lubricating oil and other hard contaminants from the feed-water. Like the hotwell pumps that discharged through these filters, each pair was capable of dealing with the entire feed-water supply. Though not normally operated in this fashion, this allowed one pair to be shut off and opened for examination or cleansing while the other pair temporarily dealt with the whole of the feed-water. The two sets supplied for *Titanic* are illustrated in Fig. 15-77.

The first stage of feed-water pre-heating was a surface heater of the horizontal 'Uniflux' type by G. & J. Weir. The surface feed heater was capable of dealing with 700,000lb

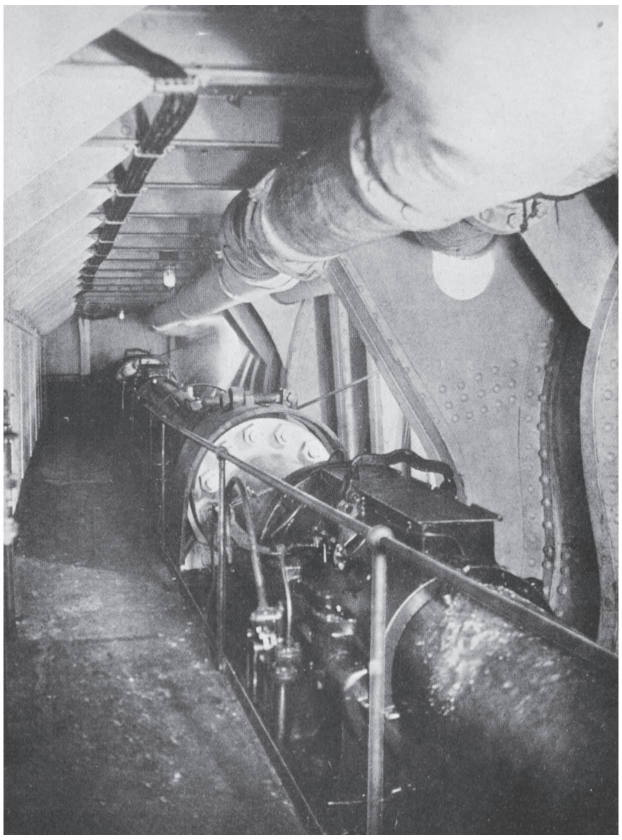


Fig. 15-91 **Shaft Tunnel** – A shaft tunnel aboard the *Mauretania*. The plummer blocks and shafting seen here are very similar to those aboard the *Olympic*-class liners and other large ships of the era. *(*Engineering*/Authors' collection)*

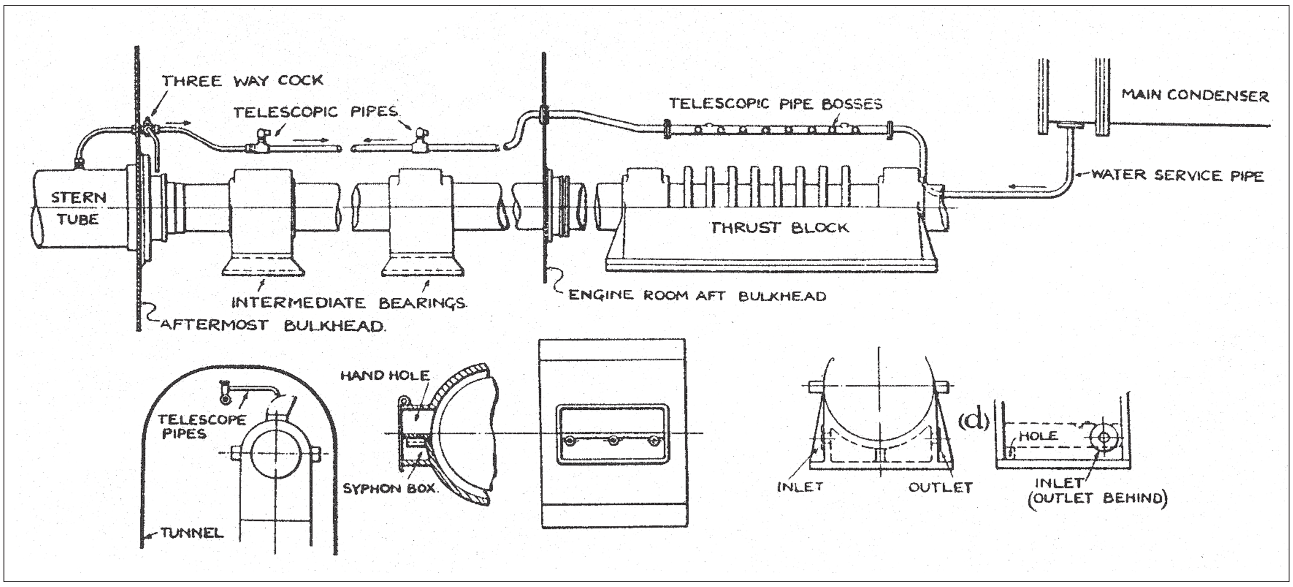

THREE WAY COCK
TELESCOPIC PIPES
TELESCOPIC PIPE BOSSES
MAIN CONDENSER
WATER SERVICE PIPE
STERN TUBE
THRUST BLOCK
INTERMEDIATE BEARINGS
AFTERMOST BULKHEAD.
ENGINE ROOM AFT BULKHEAD
HAND HOLE
TELESCOPE PIPES
SYPHON BOX.
TUNNEL
(d)
HOLE
INLET
OUTLET
INLET (OUTLET BEHIND)

Fig. 15-92 **Thrust Block Cooling Water Service** – Diagram illustrating water service supply for cooling the thrust blocks, shaft bearings and stern tube gland. Water service was also supplied for the main bearings and crosshead guides of the reciprocating engines. Water was obtained either from the main condenser water boxes or from taps off of the discharge pipes of the main circulating pumps.

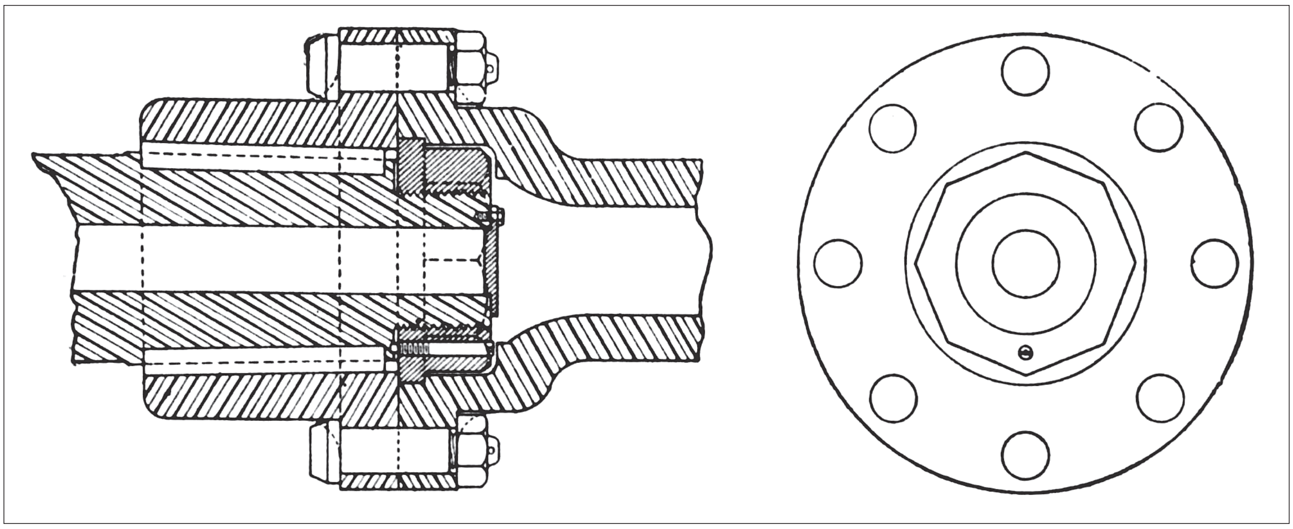


Fig. 15-93 **Demountable Tailshaft Coupling** – Typical of the couplings used on the wing tail shafts, which permitted their outboard withdrawal. *(Scott Andrews collection)*

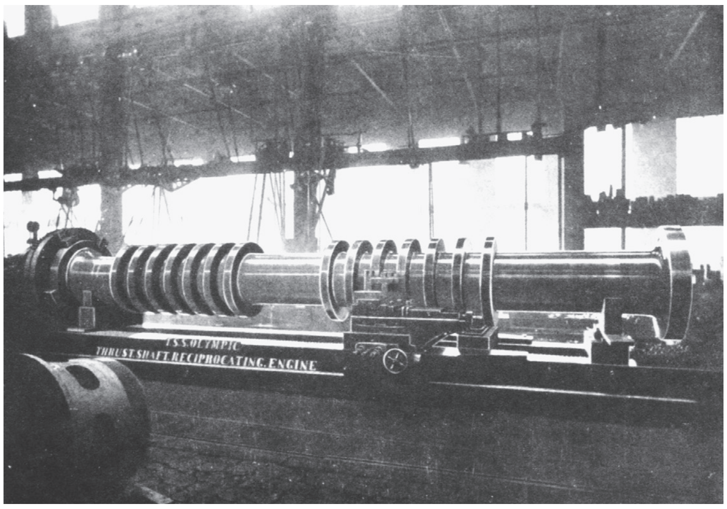

T.S.S. OLYMPIC
THRUST. SHAFT. RECIPROCATING. ENGINE

Fig. 15-94 **Thrust Shaft** – One of *Olympic*'s thrust shafts in the lathe. *(*Engineering*/Authors' collection)*

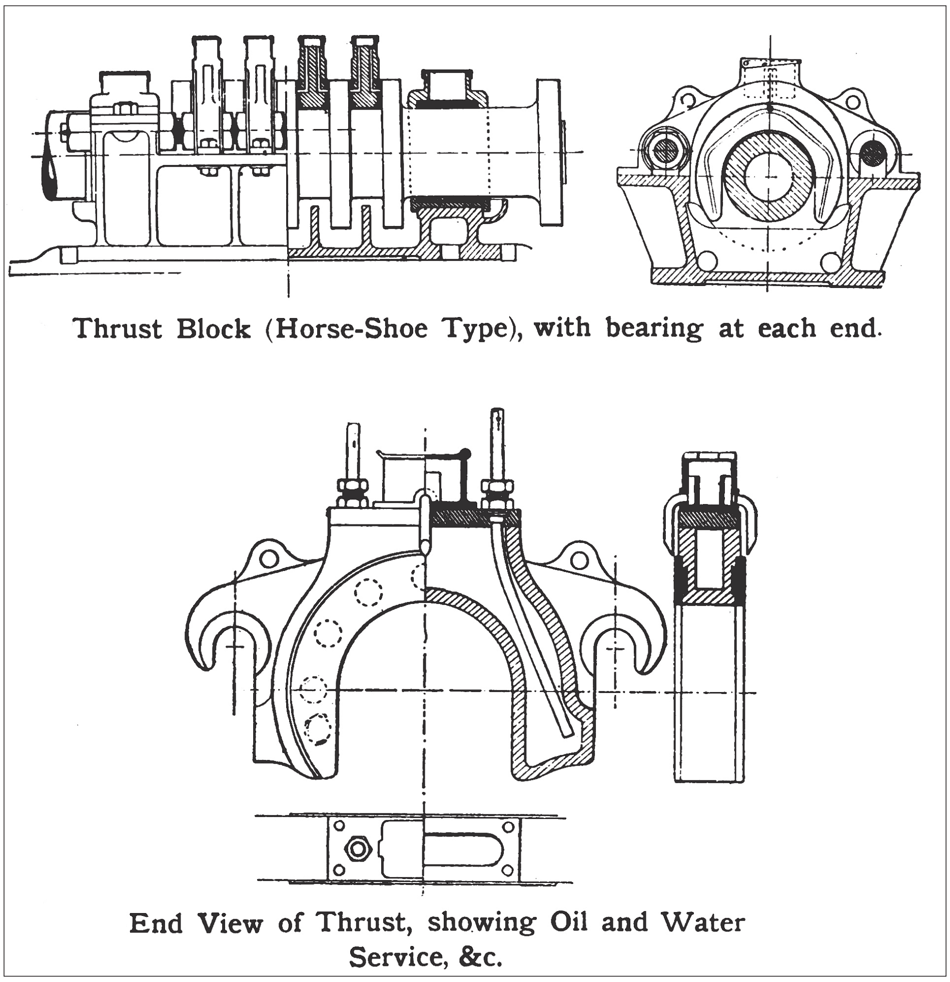

Thrust Block (Horse-Shoe Type), with bearing at each end.
End View of Thrust, showing Oil and Water Service, &c.

Fig. 15-95 **Thrust Shaft and Thrust Block** – A common 'horse-shoe' thrust block assembly. Although this thrust block is much smaller than the massive units employed in the *Olympic*-class liners, the principal components common to all thrust blocks of this design are illustrated here. *(Scott Andrews collection)*

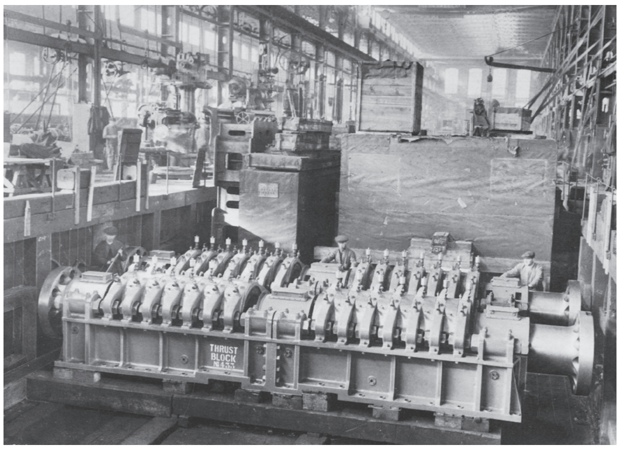


Fig. 15-96 **The Reciprocating Engine Thrust Blocks** – This pair of thrust blocks awaits installation aboard *Britannic. (H&W/ Authors' collection)*

of water per hour when supplied with 50,000lb of exhaust steam per hour from the main generator sets at a pressure of about 5PSIG. In this heater, the feed-water flowed through tubes, while the supplied steam passed through the shell of the heater and around the tubes. This made efficient use of the heat contained within the exhaust steam from the main generator sets, and raised the temperature of the feed-water from 70°F to 140°F. (At this point, the steam from the generator sets, having condensed on its way through the surface heater, was drained off to the feed-water tanks where it was added back into the feed-water supply.) The surface heater was similar in both form and construction to the main and auxiliary condensers. The shell was of mild steel and the doors of cast iron. The tube plates were of rolled brass and the tubes of solid-drawn brass. There was also a horizontal 'Uniflux' surface feed-water heater able to deal with up to 350,000lb of feed-water per hour and condense 16,080lb of exhaust steam per hour from the heating and cooking apparatus exhausts. A Weir 'Mono' type air pump having a 12in steam cylinder, 18in pump barrel and a 12in stroke was fitted in connection with this heater to maintain a vacuum of 10in.

From the surface feed heater the water passed to a Weir direct-contact heater, placed high on the forward bulkhead of the Reciprocating Engine Room at the level of the Saloon Deck (D), in order to get as great a hydraulic head of pressure as possible. The direct-contact heater used the exhaust steam from the various auxiliaries (except the steering engines, which exhausted directly to the main condensers) to raise the temperature of the feed-water from 140°F to a temperature of 212°

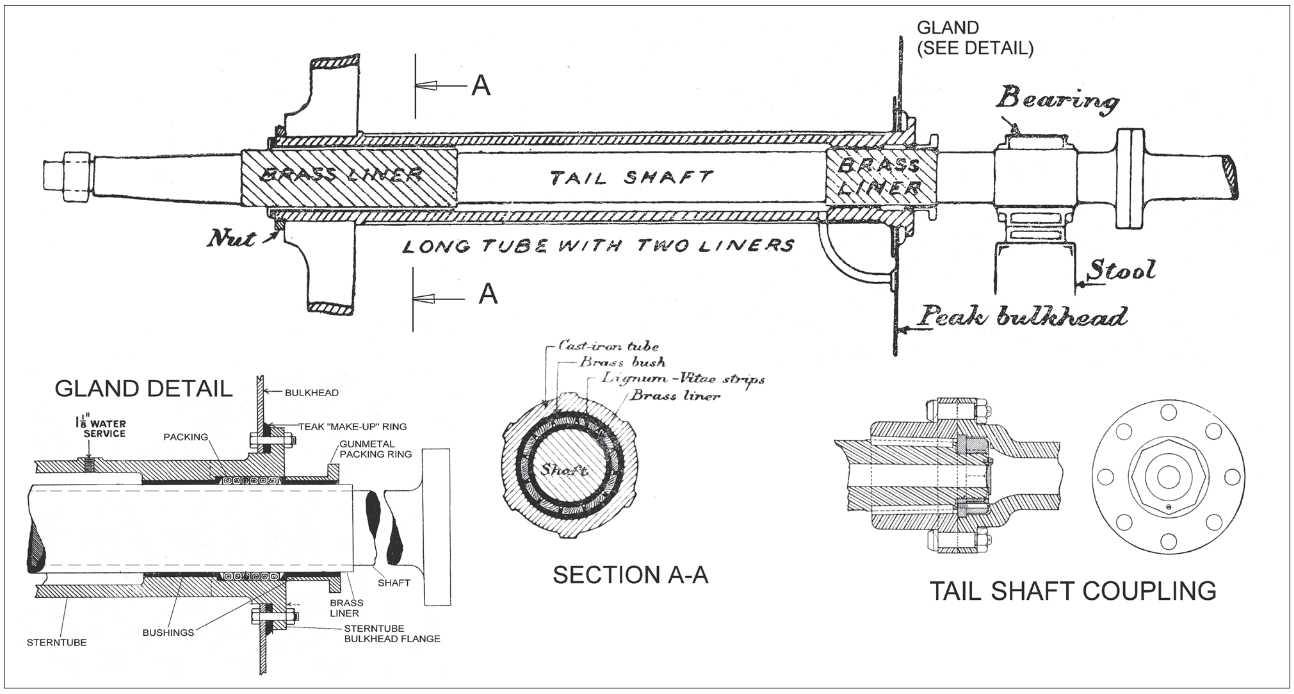

GLAND
(SEE DETAIL)
A
Bearing
BRASS LINER
TAIL SHAFT
BRASS LINER
Nut
LONG TUBE WITH TWO LINERS
A
Stool
Peak bulkhead
GLAND DETAIL
BULKHEAD
1⅛" WATER SERVICE
TEAK "MAKE-UP" RING
PACKING
GUNMETAL PACKING RING
SHAFT
BRASS LINER
STERNTUBE
BUSHINGS
STERNTUBE BULKHEAD FLANGE
Cast-iron tube
Brass bush
Lignum-Vitae strips
Brass liner
Shaft
SECTION A-A
TAIL SHAFT COUPLING

Fig. 15-97 **Stern Tube and Parts**. *(Scott Andrews collection)*

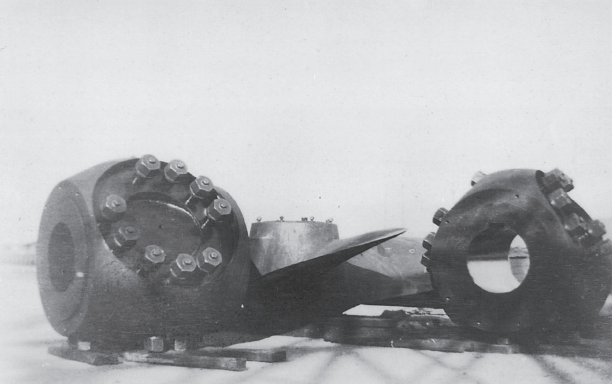


Fig. 15-98 **Steel Propeller Hubs** – Propeller parts photographed along side the Thompson Graving Dock, awaiting installation. Seen here are the two cast-steel hubs of *Olympic*'s wing propellers; the nuts which will hold the blades to the hub, or 'boss' can be seen partly run up onto the studs. In between the two bosses lays the center propeller. *(Peter Davies-Garner collection)*

to 230°F depending on the amount of exhaust steam available. An illustration of this heater is given in Fig. 15-78, while the basic internal arrangement is shown in Fig. 15-79. The shell was of mild steel, lagged with double-ply hair felt and sheathed with galvanized sheet iron. The direct-contact heater was designed with an internal float control that automatically regulated the steam supply to the feed pumps and hotwell pumps, causing these auxiliaries to work in unison. In a heater of this type, the water that was to be heated came into direct contact with the steam imparting the heat, hence the name. The feed-water was pumped in through the top through a spring-loaded valve, while the exhaust steam from the auxiliaries entered through a valve at the side. The water entering through the top fell onto a perforated conical dispersion plate, which caused the water to fall in a shower of droplets through a perforated cylinder through which the steam was being admitted. This action simultaneously heated the feed-water and condensed the incoming exhaust steam while removing a large part of the dissolved air contained in the feed-water, thereby nearly eliminating one of the primary sources of pitting and corrosion within the boilers. The liberated air was removed from a collector at the top of the heater, either by venting to the atmosphere or by vacuum from a connection to one of the condensers. From the bottom of the direct-contact heater, the filtered and pre-heated feed-water finally gravitated to the suction side of the main feed pumps.

There were four pairs of main feed pumps, two pairs being located on each side of the ship in the forward wings of the Reciprocating Engine Room. Each pair of these pumps was capable of supplying as much as half of the maximum volume of feed-water required. The feed pumps were Weir's vertical direct-acting type with steam cylinders of 19in, pump barrels having a diameter of 14in, and a 28in stroke. The water ends were of cast iron and were fitted with gunmetal liners, gunmetal buckets, manganese bronze pump rods, and bronze valves in gunmetal seats. The water valve chests for the feed pumps were cast iron and bolted directly to the pump chambers. All the feed pumps were interchangeable so far as feeding the boilers was concerned. An illustration

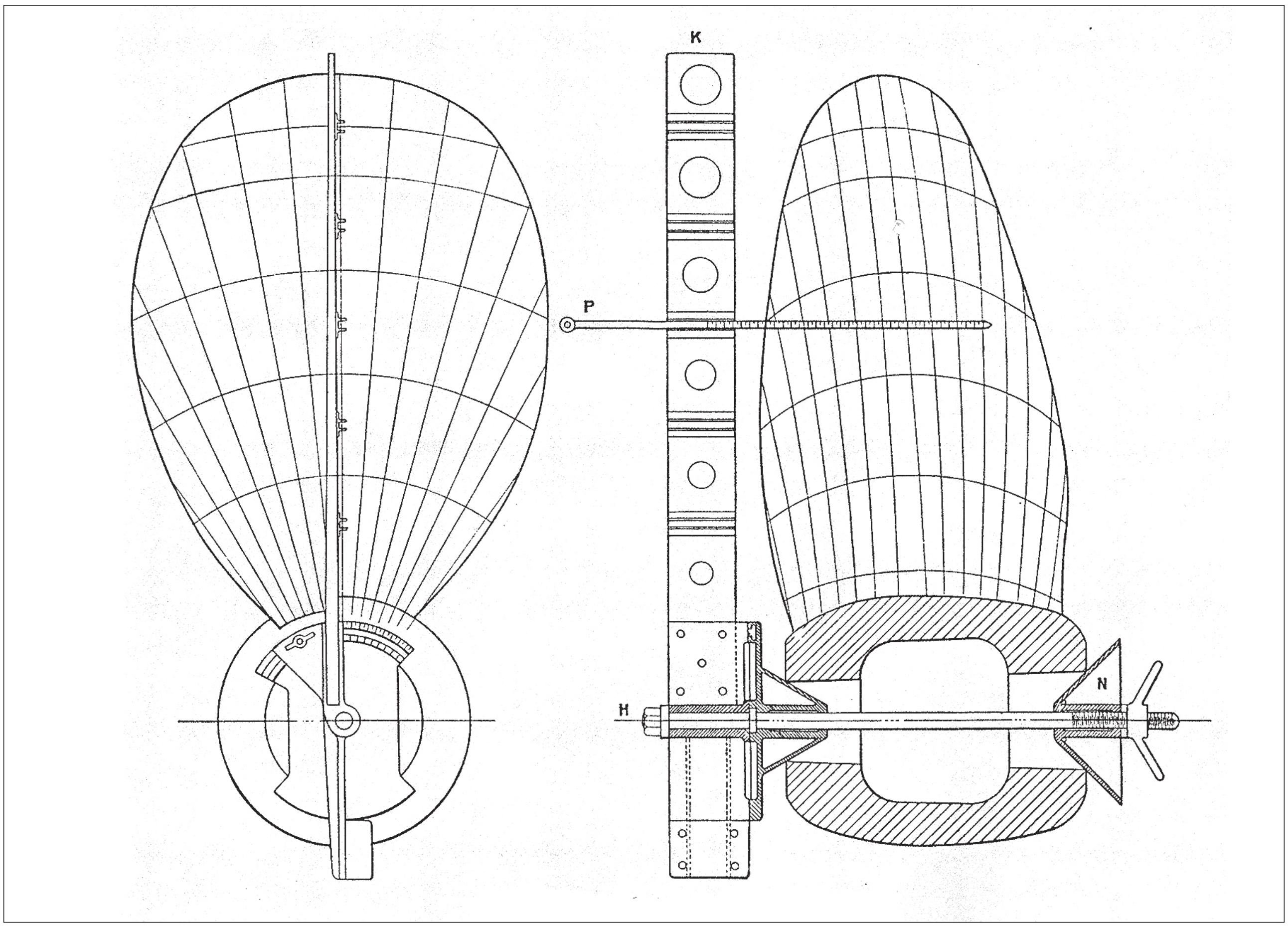


Fig. 15-99 **Pitch-Measuring Instrument** – The term 'pitch' when referring to screw propellers is the angle of the blade which effected the distance the propeller would advance during one revolution. This illustration shows one of the types of pitch-measuring instruments in use during *Titanic*'s era. In this instrument the radial batten was of dry, well-seasoned wood which was practically unaffected by atmospheric conditions. The dial plate was marked off in degrees, and each angular movement usually was 5°. The horizontal staff or measuring rod was of mahogany, fitted with a metallic tip so that it touched the blade face in line with the edge next to the batten and was capable of sliding in the guides on the batten. It could be marked in inches and fractions of an inch, but if the angular movement was always 5° the staff could be marked with one-sixth of an inch as the unit, as then each unit for that angular movement meant one foot of pitch. A useful addition to the installation was a metallic scale marked on the four edges with units to suit four different angular movements and arranged to be secured to the measuring rod at the part where it slid in the guides attached to the batten. A reference mark or score was on each guide for this purpose.

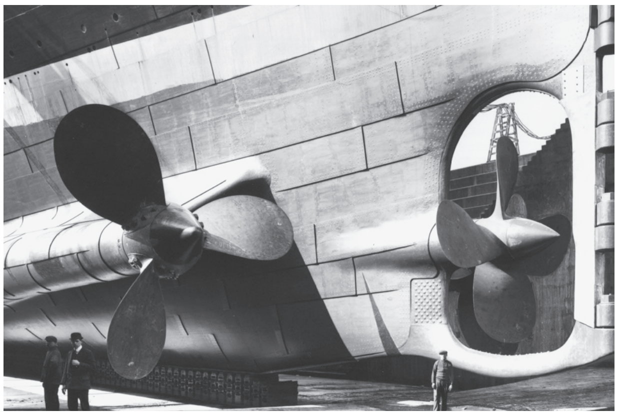


Fig. 15-100 **The Center and Wing Propellers** – The recently installed port wing and center propellers of *Olympic* seen just prior to her completion, in a photograph taken while she lay in the Thompson Graving Dock. *(H&W/Authors' collection)*

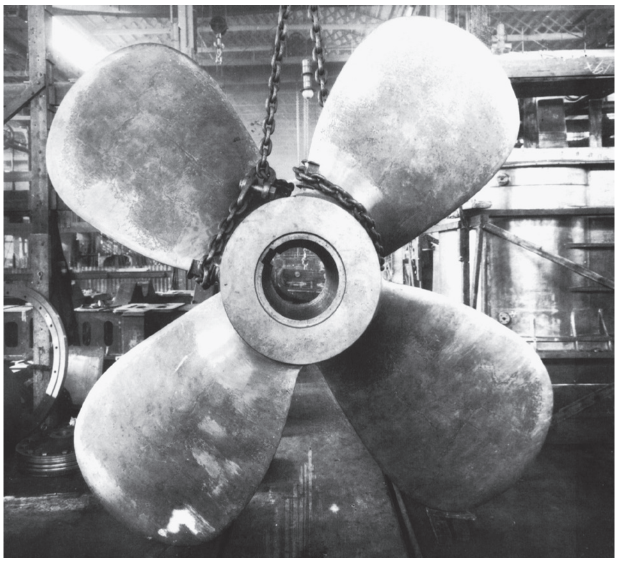


Fig. 15-101 **The Center Propeller** – *Olympic*'s center four-bladed propeller. *(*The Shipbuilder*/Authors' collection)*

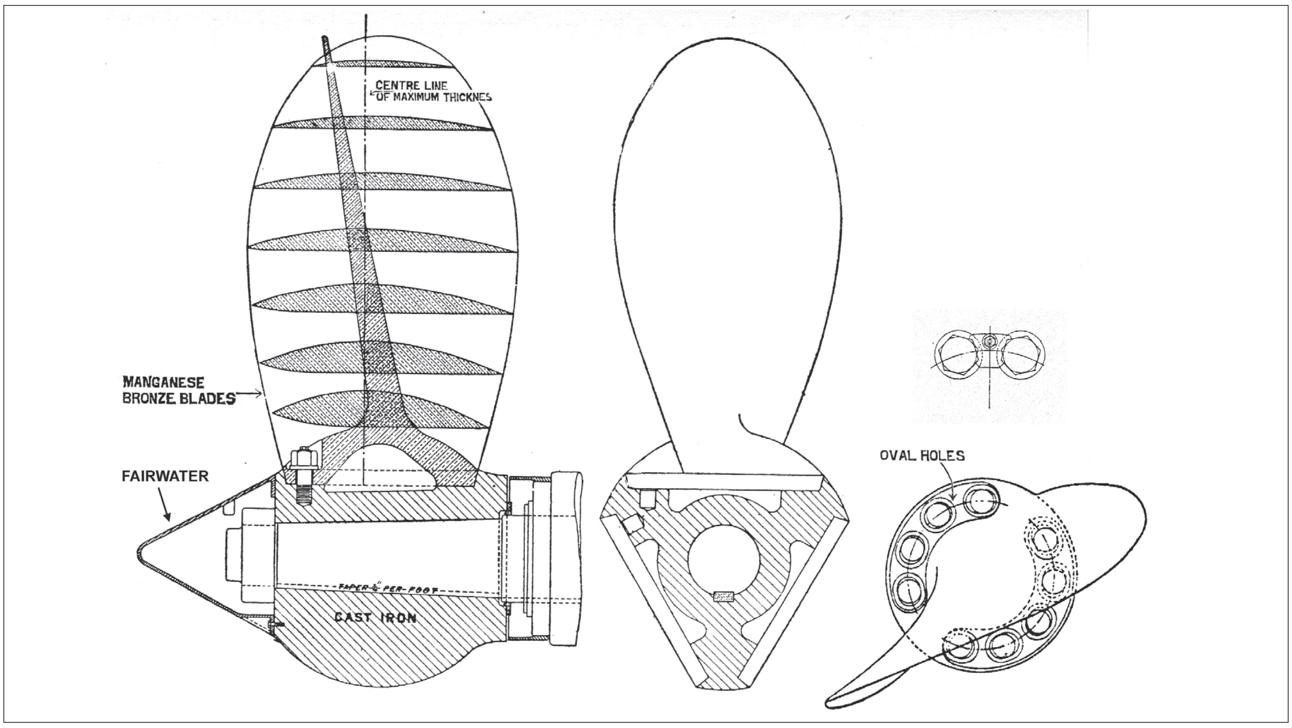


Fig. 15-102 **Three-Bladed Screw** – A three-bladed propeller of the built-up type, having separate blades and hub. The flange at the base of each manganese bronze blade was seated within a circular depression and was fastened by nuts and locking pins to studs threaded into the steel hub. The blade flanges had oval holes so that their position could be shifted, allowing the pitch to be increased or decreased as was desired. Once the desired pitch was obtained, 'cod pieces' were fitted into the ends of the holes to fill up the vacant space in order to prevent the blades from shifting. *(Scott Andrews collection)*

of one pair of feed pumps is given in Fig. 15-80 with the basic internal component illustrated in the cross-section given in Fig. 15-81.

The return feed piping from the main feed pumps to the boilers was divided into three sections. An independent main and auxiliary pipe was supplied for Nos 1 and 2 Boiler Rooms, for Nos 3 and 4 Rooms, and for Nos 5 and 6 Rooms, in order to ensure a better distribution of the feed-water. In addition to the main feed pumps, a large duplex pump was placed adjacent to each of Boiler Room Nos 2 though 6 in separate dust-tight compartments, so that the working parts were protected from injury by the affects of exposure to coal dust. Of Harland & Wolff's own design, these vertical duplex pumps were intended for auxiliary feed purposes, working the ash ejectors, boiler circulation, and other duties. Each pump had two 12in-diameter steam cylinders, two 8in pump barrels and a 12in stroke. The materials used in their construction were similar to those of the main feed pumps.

A set of valves was provided higher up within the engine casings which allowed for the occasional operation in the non-condensing mode of certain portions of the auxiliary equipment. In this mode of operation, the waste steam from these engines was redirected to the escape pipes that were run up the forward and after sides of the fourth or dummy funnel, where the steam was simply blown off to the atmosphere. An example of such a case where this sort of operation was necessary was during a short period of time spent in drydock. During such short lay-ups, the ship's lighting and refrigeration plants and pumps such as those that charged the fire mains were required to remain active even though there was no supply of circulating water available due to the sea chests for those pumps not being submerged. A number of photographs, such as those taken of *Titanic* while in the Graving Dock at Belfast, or of *Olympic* taken while in the floating drydock at Southampton, show plumes of steam being blown off the exhausts of the dummy funnel.

The evaporating plant

For making up loss in the feed-water supply, three evaporators were placed on the starboard side at the after end of the Turbine Engine Room. These were the Quiggins Patent type, supplied by the Liverpool Engineering & Condenser Co. Each evaporator had a capacity of 60 tons per twenty-four hours, a rate that could be maintained even after several days' use. The heating surfaces were of the flat grid type, made from solid drawn copper tubes, and the shells were of cast iron. Each heating surface unit was interchangeable and could be separately withdrawn from the evaporator.

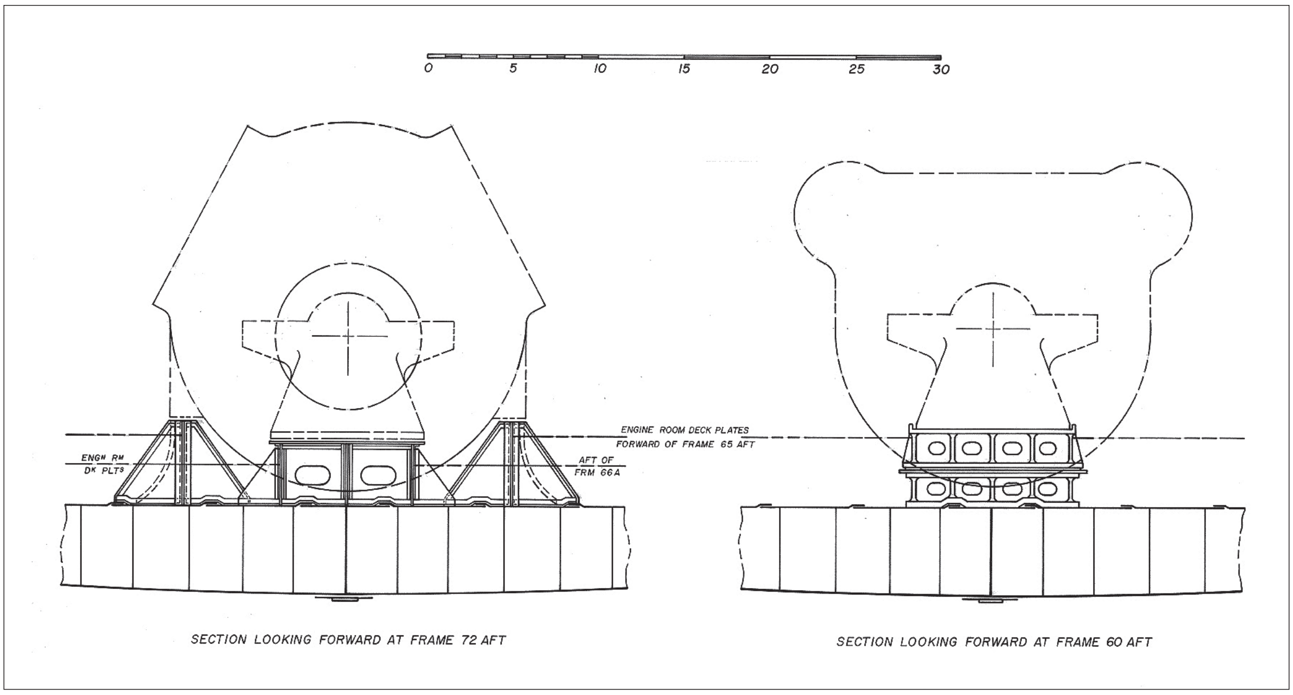


Fig. 15-103 **Turbine Seats – Section Views**. *(Illustrated by Scott Andrews)*

The joints were of the grooved type. Being metal-to-metal, they did not require any jointing material, and remained perfectly tight under any variation of pressure and temperature. The shells were lagged with double-ply hair felt and sheathed with galvanized sheet iron. An automatic regulator fitted on each evaporator controlled the feed-water supply to the evaporators. The feed-water supply to the evaporators was supplied by an independent, vertical duplex steam feed pump, having two 5½in-diameter steam cylinders, two 6in pump barrels and a 6in stroke. Mumford Ltd supplied this pump. The vapor produced by the evaporators could be directed to the condensers, feed heater, feed tanks or distillers as required. Two of the evaporators are shown in Fig. 15-87.

For the purpose of producing fresh water for drinking, two distillers were provided, taking vapor from the evaporators. These were located at a higher level than the evaporators, both to provide gravity drainage to the fresh water storage tanks and to prevent the possibility of lifting sea water from the evaporators due to priming. The distillers were of the 'Climax' fresh water, low-pressure type by Hocking & Co. Ltd, Liverpool, and had a capacity of 5,000 gallons per twenty-four hours. Both distillers were located on a flat at the Lower Deck (G) level against the bulkhead dividing the engine rooms, within the recess provided for the eduction pipe and discharge valves of the starboard main condenser. Vapor entering from the evaporators was condensed by passing through copper coils surrounded by circulated sea water. From the condensing coils, the water passed through a charcoal filter to remove any residual chemical impurities. From here the water flowed to the fresh water storage tanks through piping which was provided with a vent open to the atmosphere. The atmospheric vent promoted aeration of the distilled water, which otherwise had an objectionable taste and odor.

Shafts, bearings and propellers

The intermediate line of shafting running between each engine and its respective tailshaft was comprised of segments between 30 and 33ft in length, all of forged steel. Each segment was carried in two shaft bearings, or 'plummer blocks', of substantial size. The bottom half of each bearing – the portion which bore the weight of the shaft – was lined with white metal. The shaft bearings were supplied with forced lubrication from the same system in the Turbine Engine Room which provided lubrication to the turbine bearings. The discharged oil from these bearings drained into the various drain pots and collection tanks provided throughout the machinery spaces, from which it was drawn by the pumps in the Turbine Engine Room. The shaft bearings were also provided with cooling water service from pumps in the Turbine Engine Room.

The intermediate shafting for each reciprocating engine was 26¼in in diameter with a 12in hole bored through the centerline. The propeller or 'tail' shaft of each outboard line of shafting was of forged steel and encased in a brass liner that was shrunk onto the shaft. These tailshafts were 28½in in diameter with a 12in hole bored

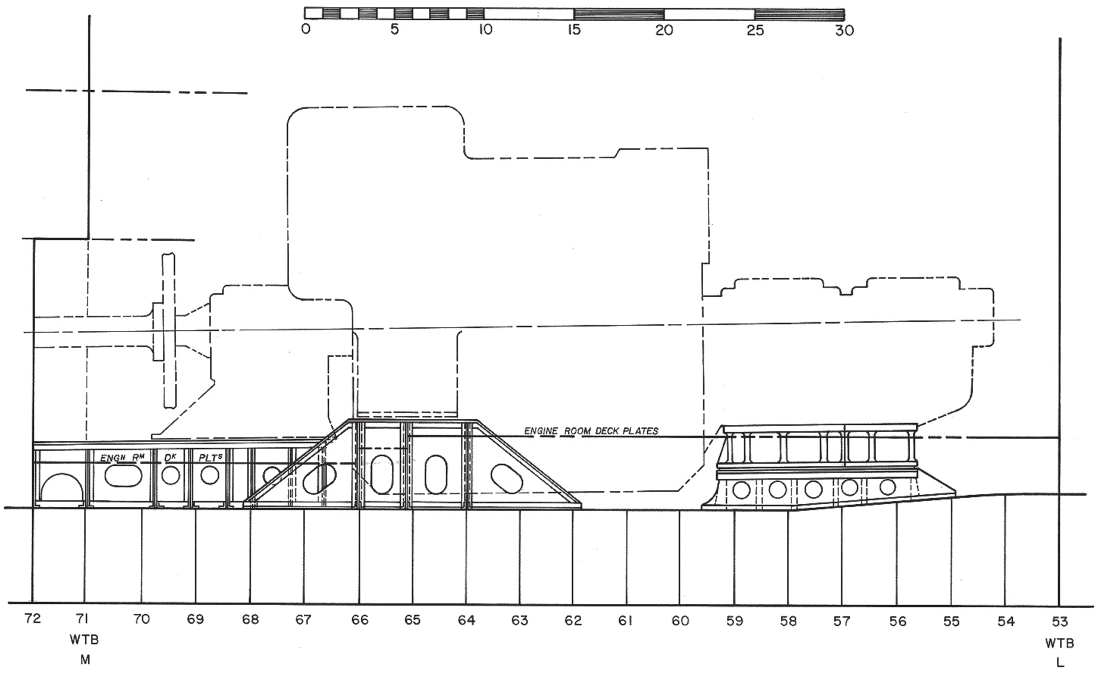

0
5
10
15
20
25
30
ENGINE ROOM DECK PLATES
ENGN RM DK PLTS
72
71
WTB
M
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
WTB
L

Fig. 15-104 **Turbine Seats – Inboard Profile**. *(Illustration by Scott Andrews)*

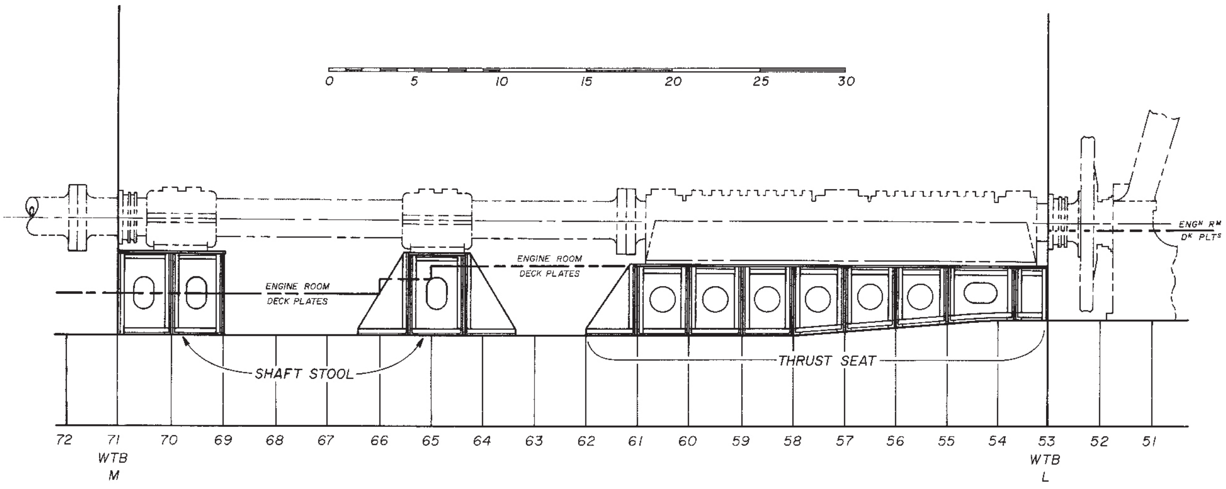

0
5
10
15
20
25
30
ENGINE ROOM DECK PLATES
ENGINE ROOM DECK PLATES
ENGN RM DK PLTS
SHAFT STOOL
THRUST SEAT
72
71
WTB
M
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
WTB
L
52
51

Fig. 15-105 **Thrust Seats and Shaft Stools** – This illustration shows the heavy seatings which carried the reciprocating engine thrust blocks and transmitted the thrust they absorbed to the hull. Also depicted here are two shaft stools, typical in form to the many more which supported the intermediate shafts along the great distance between the engines and the stern tubes. *(Illustration by Scott Andrews)*

through the center, and reduced at the after end by short lengths of taper to 6in. This last segment was made with a demountable coupling of the type shown in Fig. 15-93 to enable withdrawal outboard through the stern tube to facilitate inspection of the shaft and interior of the stern tube, and to permit renewal of the bearing surfaces. The wing shafts were located at a height of 12ft 3in above the molded line of the keel. At the propeller, they were located 19ft 6in outboard from the centerline of the ship. However, the crankshafts of the reciprocating engines were located 16ft 3in outboard from the centerline of the ship, measured at the point of intersection between the crankshaft centerline and the vertical centerline of the forward low-pressure cylinder. This required the centerlines of the shafts and of the reciprocating engines to be splayed outward when heading aft.

At its forward end, each outboard shaft terminated at a large thrust block assembly.

When the engines were turning ahead or astern, the revolutions of the propeller drove the ship forward or backward. This thrust occurred as a result of the propeller exerting a force along the shaft in the respective direction. The crankshafts of the reciprocating engines, however, revolving in simple bearings, were not designed to absorb this thrust. To take up this thrust and convey it to the hull, thrust blocks were introduced just abaft the reciprocating engines. These served to transmit the fore-and-aft thrust generated by the propeller to the ship's structure. The thrust blocks were situated in the Turbine Engine Room, just aft of the watertight bulkhead dividing this compartment from the Reciprocating Engine Room. They were of the 'horse shoe' bearing type, each having two sets of six double-sided thrust bearings, or 'shoes' seated in between collars machined onto the thrust shaft, plus a seventh single-sided collar at the forward end of each set, the seventh collar having a bearing surface on the 'ahead' side only. The thrust shaft in each of these assemblies was machined from a steel forging and was 26ft 11in long and 27in in diameter with a 9in hole bored through the centerline. There were fourteen collars machined onto each shaft, these collars being divided into two sets of seven; a central shaft bearing was fitted between these sets in addition to the usual end bearings. This was a practice first adopted by Harland & Wolff in the construction of large engines with the building of the *Oceanic (II)* in 1899. The shaft bearings and thrust shoes – all of which were lined with white metal, an alloy consisting of 10 parts tin, 1 part antimony and 1 part copper – were mounted on a heavily constructed cast-steel bedplate. Large adjusting screws located on each side of, and parallel to, the thrust shaft maintained the fore-and-aft positioning of the thrust shoes, with each shoe having separate jamb nuts. This allowed individual adjustment of each shoe, thereby permitting the load to be distributed evenly over all of the collars. The total surface area of the thrust bearings in each block was 6,860sq.in. As in the case of the propeller shaft bearings, forced lubrication was provided from the pumps and tanks in the Turbine Engine Room. Additionally, cooling water service was provided to the thrust shoes and shaft bearings. A photo of an identical pair of thrust blocks for *Britannic* is reproduced in Fig. 15-96.

The line of shafting driven by the turbine engine was 20½in in diameter with a 10in hole bored through the centerline. The tailshaft in this case was of the same construction as the tailshafts for the wing propellers, but 22½in in diameter, with a 10in hole tapered to 5in at the after end. Due to the close proximity of the stern frame to the exit point of the center tailshaft, it was not possible to provide the convenience of outboard extraction of the center tailshaft, the shaft being withdrawn inboard instead. This obviated the need to provide any sort of special coupling with the line of shafting as was done with the wing tailshafts. The center shaft exited the ship at a height of 12ft 3in above the keel and was fitted on a slight upward inclination parallel to the center axis of the turbine. At the opposite end, the center of the shaft was located at about 15ft 4in above the keel at the point where it was coupled to the end of the aft spindle of the turbine rotor.

Each tailshaft exited the ship through an assembly known as a 'stern tube'. The stern tube served as a bearing to support the weight of the propeller and tailshaft and as a gland around the shaft to prevent water from entering the hull. Both the bossing in the stern frame and the wing brackets were align-bored with respect to the engines and shafts to receive the stern tubes. The bearing surfaces of the stern tubes were lined with lignum vitae, an extremely dense oily wood. This wood was installed in long longitudinal strips, between which water was allowed to pass freely in order to lubricate the tailshaft. To prevent water from entering the ship, the inboard end of the tubes were fitted with an adjustable gland called a 'stern gland'. When under way, the packings of the stern glands were usually slackened a bit to allow a little seepage in order to keep the rubbing surfaces cool.

The wing propellers each had three manganese-bronze blades fastened onto a cast-steel boss by special high-strength studs and nuts. These massive propellers had a diameter of 23ft 6in, a pitch of 34ft 6in, and a surface area of 160sq.ft. The center propeller, if the same as *Olympic*'s, would have been four bladed and of solid construction, cast of manganese bronze. This propeller had a diameter of 17ft, a pitch of 14ft 6in, and a surface area of 125sq.ft.[22] The aforementioned figures represented a change over the specifications of the propellers originally designed for the *Olympic*-class liners. The initial propellers installed on the *Olympic* differed in that the pitch of the wing screws was 33ft,[23] and the diameter of the center screw was 16ft 6in; the remaining dimensions were the same on both ships.

For the wing screws, provision was made for slight alteration of the pitch through use of elongated boltholes in the base of each blade, with brass or lignum vitae stops being inserted between the mounting studs and the edges of the holes to prevent the blade from shifting. The bosses for the wing screws and the hub of

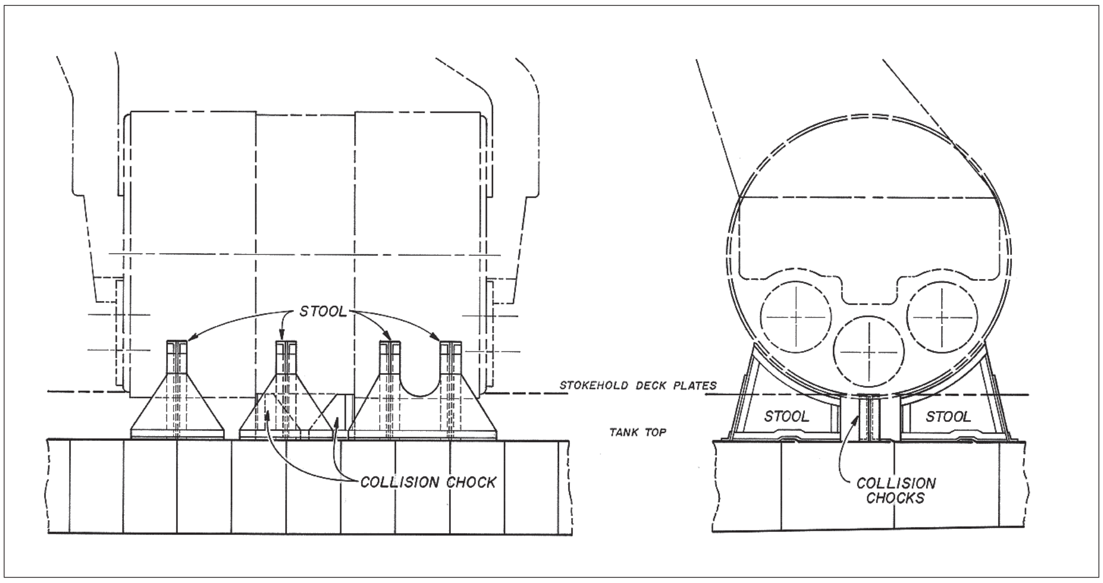


Fig. 15-106 **Boiler Stools – Double-Ended Boilers –** Elevation and end views illustrating the stools and collision chocks of the double-ended boilers. Boiler 2B is shown here; the others were similar. Note: The boilers were numbered 1, 2, 3, etc. denoting the boiler room in which they were located, and then A, B, C, D or E from port to starboard. *(Illustration by Scott Andrews)*

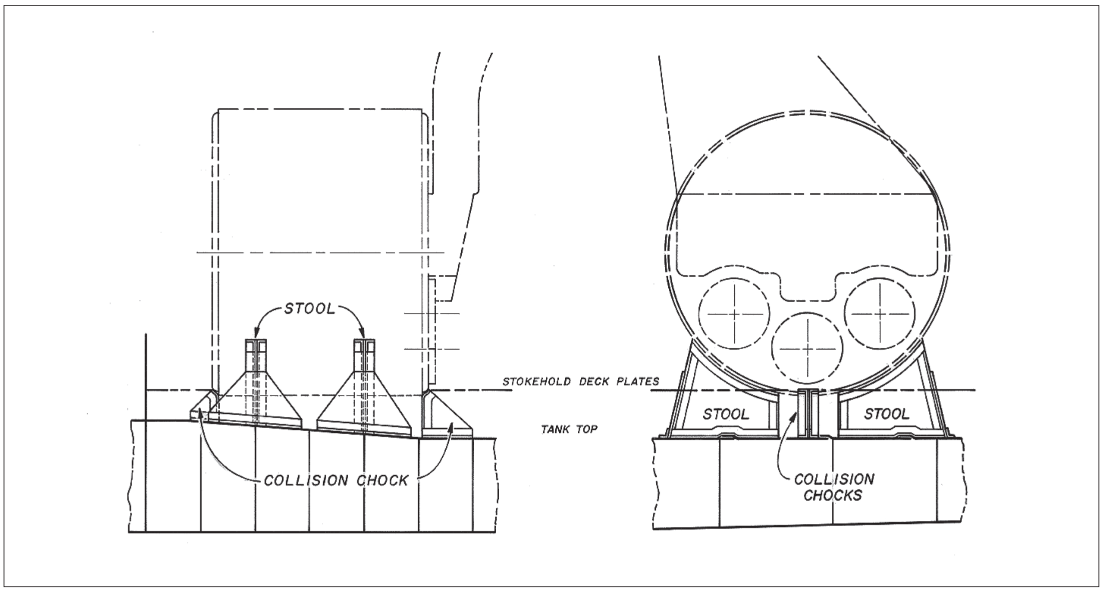


Fig. 15-107 **Boiler-Stools – Single-Ended Boilers –** Elevation and end views illustrating the stools and collision chocks of the single-ended boilers. Boiler 1B is shown here; the others were similar. *(Illustration by Scott Andrews)*

the center screw each contained a tapered hole which had a key-way machined along one side to accept a key inserted into a slot machined into the tailshaft. Holding each propeller in place was a barrel-shaped retaining nut run up tight against the boss or hub on the threads machined into the end of each tailshaft. To prevent slackening back of these nuts, right-hand threads were used on shafts having a left hand rotation and vise versa. Additionally, each nut was secured with a keep-plate. To prevent water from entering the space between the shaft and hub or boss and causing corrosion, packing was installed at the end facing the stern tube. At the after end of the propeller, a cone-shaped cap, or 'fairwater', was installed over the nut, both to streamline the end of the propeller and to protect the nut and shaft from corrosion, a sealing compound being applied between cap and propeller to exclude water. Portland cement was applied as a fairing compound to fill the bolt recesses around the fairwater of each propeller as well as to the blade nuts of each wing propeller. An illustration of a three-bladed propeller of built-up construction is given in Fig. 15-102.

SEATINGS FOR PROPELLING MACHINERY & BOILERS

Main engine seats

Titanic's engines were firmly bolted to solid foundations so they could run steadily and smoothly with a minimum amount of vibration. In a ship, the foundations of the engines, or 'seatings', was a tabular structure of plates and bars, the design of which had substantial rigidity. If the foundations were of light construction and flexible enough to allow relative movement or straining of its parts, the swaying of the engines from side-to-side as the vessel rolled would eventually break down the seatings. The vibratory effects of the heavy oscillating parts of the reciprocating engines would also have the same effect. Furthermore, in such a case, the bolts holding the engines to the seatings (the 'holding-down' bolts) would not act together; some, more strained than others, would loosen the contiguous riveting of the seatings or cause fracture of the cast-iron bed-plates of the engines directly clamped by them. Even with massive seatings, engines in rapid movement were liable to vibrate, and the resulting vibrations would be transmitted through the structure of the hull.

Titanic's engines were designed to run with minimal tendency toward vibration. Not only were the engine seats and the hull immediately contiguous to them massively constructed, the contiguous plating around them was as well. This was evidenced by the increased strength of the bottom and side framework throughout the machinery spaces.

An engine seat can be described as a thick horizontal plate, supported and stiffened by vertical bearer plates, disposed both athwartships and fore-and-aft, the whole forming a rigid tabular structure. This description applies not only to engine seats constructed in built-up fashion on top of the Tank Top plates, as were the after seats for the turbine, but also to engine seats designed and built as an integral part of the ship's double bottom, as was the case with the seats beneath the reciprocating engines. The precise formation of the seats depended on the design of the framework of the hull and bottom and on the design of the engines. It was essential that the bearers were interwoven; if they were all parallel, their freedom to trip would permit the whole seating to strain from side-to-side or fore-and-aft. The forces contributing to this could be severe: as the ship rolled and pitched, the massive reciprocating engines, their heavy cylinders elevated high above the Tank Top, would swing in unison with the ship, setting up a continuous rocking effect. As the engines were only held in place by their bolt attachment to the top of the seats, the rocking motion would eventually work the bolts loose and the engines' heavy moving parts would then induce a vibrating effect.

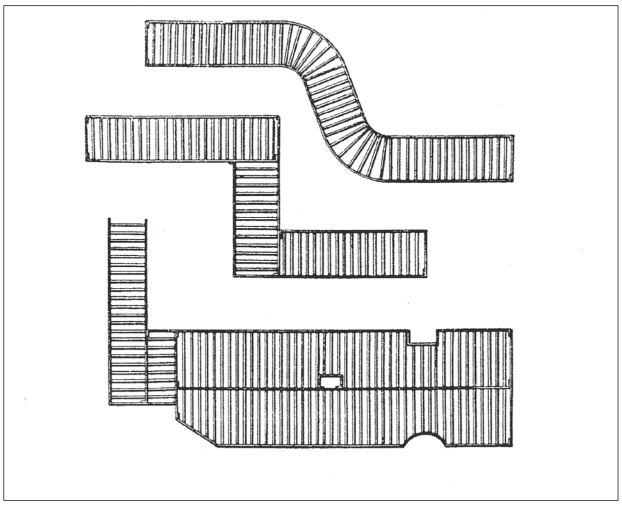


Fig. 15-108 **Typical Form-Fit Gratings.**

The vertical position of the engines in the ship was determined by the height of the shafts above the keel. The correct elevation of the reciprocating engines was achieved by increasing the depth of the tank floors beneath the Reciprocating Engine Room from bilge to bilge – or, in other words, raising the height of the Tank Top beneath the engines. Because a cellular double bottom was employed, the reciprocating engines sat directly on the Tank Top, although not in actual contact with it. Within this area, the reverse frames were doubled, while the thickness of the floors was increased and the vertical angles connecting the floors, intercostals and the top edges of the intercostals were doubled. Thick plating covered the entire Tank Top under the engines and the plate landings within this area were double-riveted, while all laps were treble-riveted. Treble riveting was also used through the straps beneath any flush seams in this area.

Elevating the Tank Top to the required level was accomplished by increasing the height of the ordinary floors to the required level and then fitting intercostal fore-and-aft bearer plates between the ordinary floors, with cross diaphragm and bracket plates to support and hold them in place. To give the necessary rigidity, in some instances some of these additional parts were increased by as much as 50 to 100 per cent in thickness from that of the ordinary floors. Due to both the additional structural supports and the increased depth from bilge to bilge, the structure beneath *Titanic*'s machinery spaces had almost no tendency to vibrate or strain upwards or downwards.

Access was provided to every part of the seatings by manholes in the deep floors and intercostal plates, these in turn being accessed via manholes in the Tank Top.

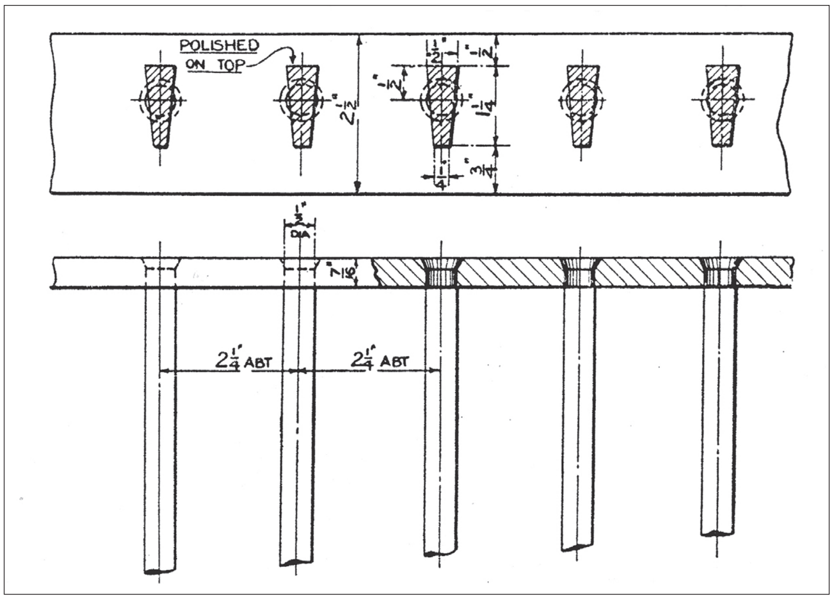


Fig. 15-109 **Spills of 'Firebar' Section** – These spills were trapezoidal in section.

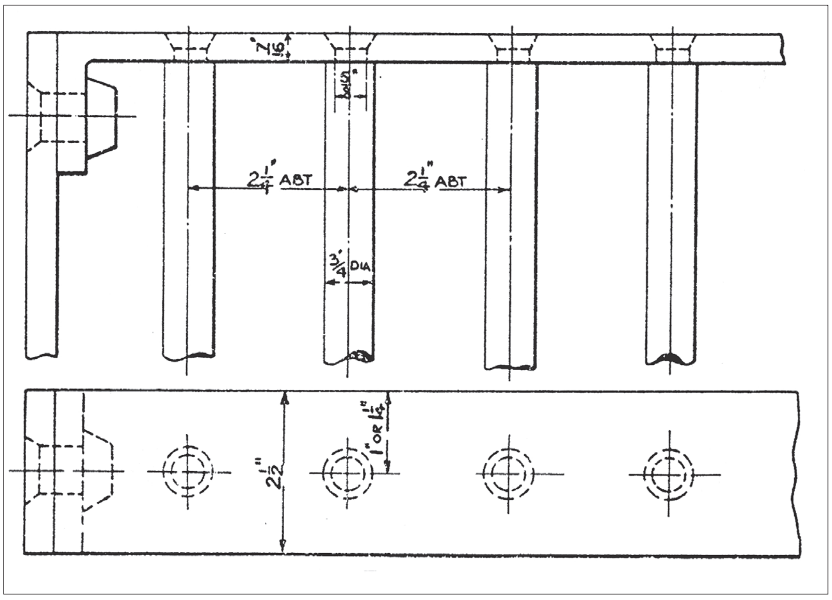


Fig. 15-110 **Spills of Round Section** – Section and partial plan view showing a grating with round spills; this was typical of what was used on *Titanic*'s fidley gratings at the tops of the boiler casings.

The bases of the engines themselves – the bedplates – were massive castings having flanges along the outer periphery to take the holding-down bolts. Additional flanges to take the holding-down bolts were provided along the interior peripheries of the open spaces formed by the athwartship girders supporting the main crankshaft bearings. These bolts were spaced about 20in apart in the fore-and-aft direction and between 12 and 18in apart athwartships, and passed through the thick top plating of the seats and also through the doublings and straps beneath this plating. In order that these would have maximum rigidity against the upward pull exerted against them, they were placed as close as possible to bearer plates below. The bolts were fitted just clear of the bearer angles to avoid fouling the riveting and to secure a flat surface for the bolt heads. The top plating along the seating was 1$^1/_8$in thick and was doubled from beneath, both by wide plate straps laid over the double angles of the floors and intercostals, and at its forward and after ends, where it was made to overlap the ordinary Tank Top plates by as many as four frame spaces. Below this area, the vertical bearer plates were made approximately 25 per cent thicker than elsewhere within the machinery spaces. The connecting angles were also of large size and thickness; they were doubled throughout, but where there was insufficient space to fit and rivet double angles, a single large one was substituted.

The engine bedplates did not sit in direct contact with the Tank Top plating, so a perfectly flush surface was not an absolute necessity. During the process of bolting the engines in place it was necessary to make the proper adjustments so that the crankshafts within them were in line with the distant stern tubes, already permanently

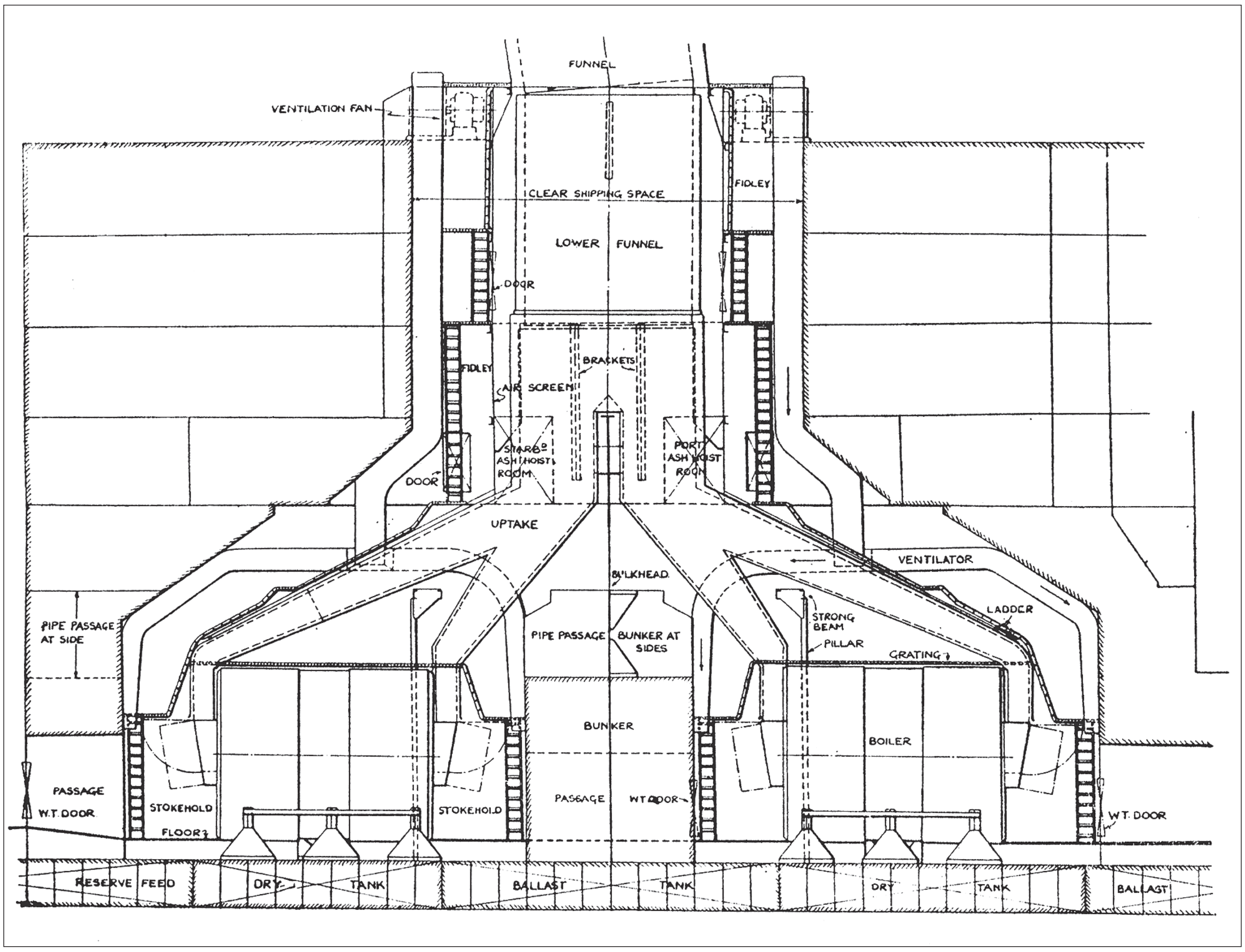

FUNNEL
VENTILATION FAN
CLEAR SHIPPING SPACE
FIDLEY
LOWER FUNNEL
DOOR
BRACKETS
FIDLEY
AIR SCREEN
STARBD ASH HOIST ROOM
PORT ASH HOIST ROOM
DOOR
UPTAKE
VENTILATOR
BULKHEAD
PIPE PASSAGE AT SIDE
PIPE PASSAGE
BUNKER AT SIDES
STRONG BEAM
PILLAR
LADDER
GRATING
BUNKER
BOILER
PASSAGE
W.T. DOOR
STOKEHOLD
FLOOR
STOKEHOLD
PASSAGE
W.T. DOOR
W.T. DOOR
RESERVE FEED
DRY
TANK
BALLAST
TANK
DRY
TANK
BALLAST

Fig. 15-111 **Fidley Ladders** – This diagram shows the arrangement of ladders and gratings in another H&W-built ship. The general features of this design are very similar to what would have been found aboard *Titanic*, including the ladders inside the fidley trunks which terminated at a 'booby hatch' on the casing top.

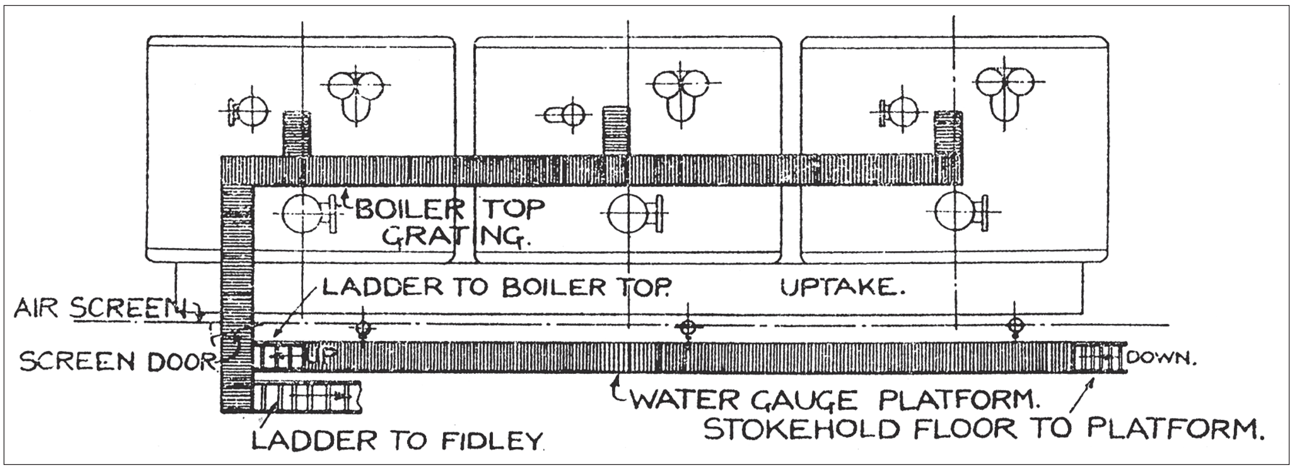

BOILER TOP GRATING.
AIR SCREEN
LADDER TO BOILER TOP.
UPTAKE.
SCREEN DOOR
UP
DOWN.
WATER GAUGE PLATFORM.
STOKEHOLD FLOOR TO PLATFORM.
LADDER TO FIDLEY.

Fig. 15-112 **Water Gauge and Boiler-Top Platforms** – Based on a H&W design, the arrangement shown in this drawing is typical of the gratings and ladders which formed the water gauge and boiler-top platforms.

fixed. To provide for vertical adjustment, the bedplates were designed so that, when they were in proper position, they were from 2 to 3in clear of the Tank Top; teakwood wedges and iron blocks were driven tightly in the vacant space between the holding-down bolts.

With built-up seatings, the holding-down bolts were of the ordinary square- or hexagonal-headed type, inserted from below, and where a bolt head could foul a bearer plate, part of it was cut off. However, when the holding-down bolts passed through the tank-top

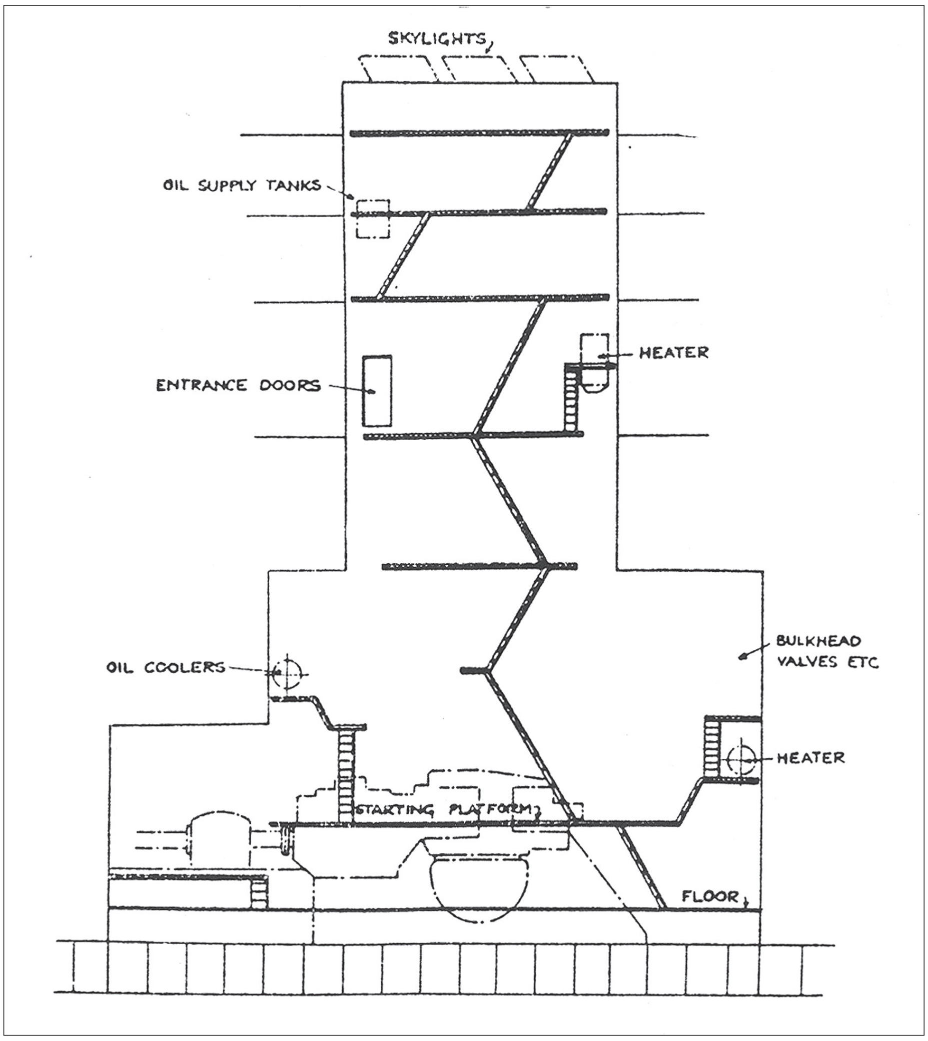


Fig. 15-113 **Ladders Within the Engine Casing** – This image serves to illustrate the network of ladders and platforms which were found within the engine casings. On *Titanic*, ladders and platforms of this type provided access to high-mounted equipment such as the direct contact heater in the reciprocating engine casing, and the lubricating oil supply tanks and emergency dynamos in the turbine engine casing. Additionally, they provided the engineers with a direct route of escape to the open decks high above.

plating, as they did with the reciprocating engines, the holding-down bolts were formed as studs in order to secure perfect watertightness. They were screwed through the tank-top plating and, both to prevent them from backing out and to relieve the thread, a lock nut was screwed onto the threads from below, a soft grommet being interposed as a further precaution against leakage. All such bolt holes were drilled and tapped before the engines were put on board, their position being accurately transferred by template from the bedplates. The holes were arranged to clear the joints of the Tank Top plating and the reverse frame and intercostal angles below. Without this clearance, they could interfere with the caulking or cut up the riveting; additionally, the lock nuts would not get a fair surface to bear up against.

The construction of the turbine engine seats was simpler in form. The seatings at the after end of the case took the form of two massive built-up stools, located on either side of the centerline. Each stool was composed of a heavy fore-and-aft vertical bearer plate topped by a thick seating plate which ran continuously across the top of the bearer plate and down the triangular fore-and-aft bracket plates situated at both ends. Each stool was stayed transversely by six brackets, arranged three per side in pairs. All of these members were connected to one another through, and stiffened by, heavy double angle bars. Additional double angle bars solidly connected the stools to the Tank Top plates. A long central box-girder seat supported the after turbine rotor spindle bearing. This was composed of two fore-and-aft bearer plates connected by a thick top plate; internal cross-diaphragms tied the bearer plates to one another across the centerline and supported the mid-portion of the top plate, while external bracket plates helped to hold the fore-and-aft bearer plates erect while stiffening and supporting the thick top plating. A three-piece, cast-iron seating supported the forward rotor spindle bearing and provided a 'floating' support for the turbine thrust block.

Thrust seats

The following description of thrust seats deals only with the seats provided for the thrust blocks of the

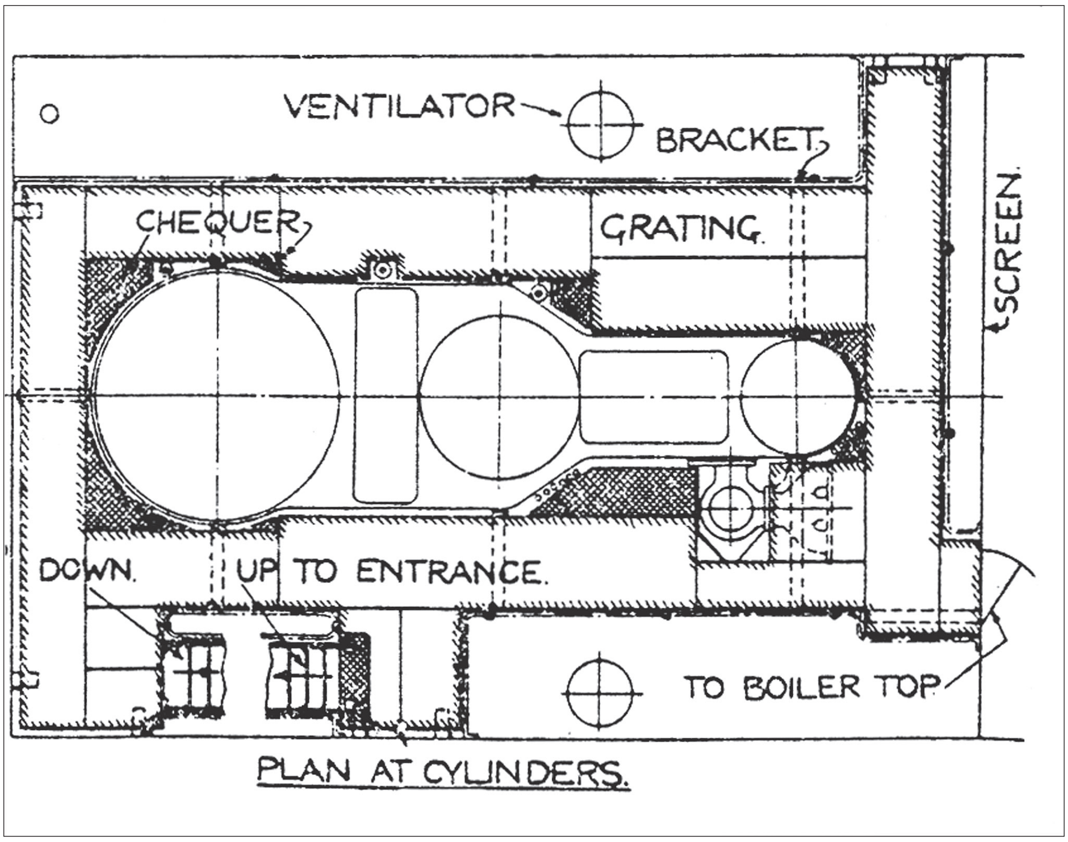

VENTILATOR
BRACKET
CHEQUER
GRATING
SCREEN
DOWN.
UP TO ENTRANCE.
TO BOILER TOP
PLAN AT CYLINDERS.

Fig. 15-114 **Platforms Around Cylinders** – This drawing, from a single-screw H&W-built freighter with a three-cylinder triple expansion engine, provides a good example of the type of gratings and chequered plates which made up the platforms around the cylinders.

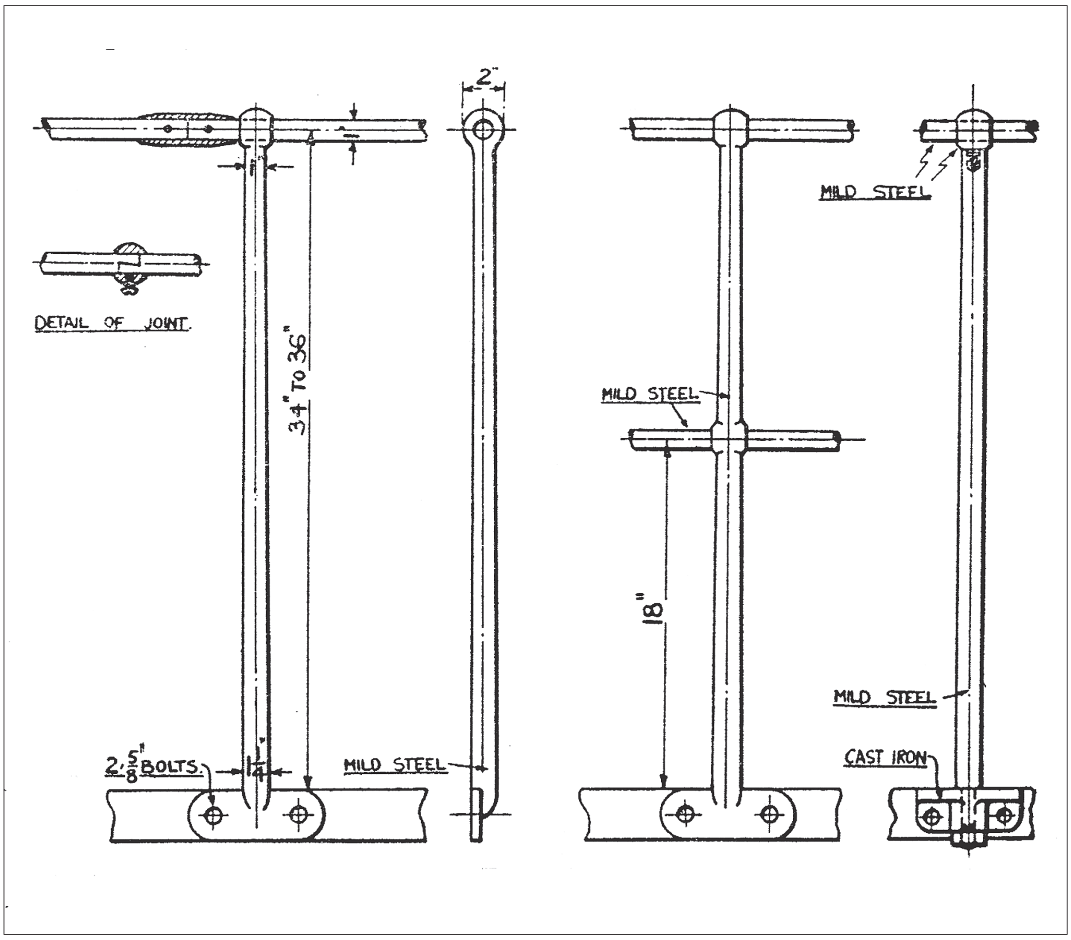

2"
1"
DETAIL OF JOINT.
34" TO 36"
2, 5/8" BOLTS.
1 1/4"
MILD STEEL
MILD STEEL
MILD STEEL
18"
MILD STEEL
CAST IRON

Fig. 15-115 **Railings** – Typical forms of railings and stanchions, and their attachments, as used in the construction of machinery space platforms. These were also very similar in form to the lightweight railings used on the deckhouse roofs above *Titanic*'s Boat deck.

reciprocating engines, which are detailed in the section describing the shafts, bearings and propellers. The arrangements for absorbing the thrust of the center propeller differed considerably due to the unique requirements of the Parson's low-pressure direct-drive turbine. As noted immediately above and in the section dealing specifically with the turbine, the thrust block for the center shaft was integral with the turbine engine and, therefore, the thrust developed was transmitted to the hull via the lower turbine casing and seats.

In order for each thrust block to effectively resist the push of the shaft and convey it to the hull without causing local straining, it had substantial seating, to which it was strongly bolted down. The thrust transmitted was not always a steady force. In heavy weather, when the propellers might alternate between rising out of the water and being deeply submerged, the thrust could repeatedly surge from zero to well above normal. This was caused by the engine racing and developing a high 'no-load' velocity when the propeller was out of the water, so that when suddenly submerged again, the rapidly revolving propeller momentarily produced an abnormally high amount of thrust.

If the thrust-blocks were mounted on foundations located too far below the level of the shaft, the thrusting effect would be concentrated on the upper part of the seating, with the result being a tendency to topple it forward, thus creating a lifting stress on the aftermost bolts, straining them and the contiguous riveting of the seating. To avoid this tendency the tops of the thrust seats were situated as near the axis of the shaft as possible. By reducing or eliminating this uneven disposition of thrust, the holding-down bolts were subjected to mainly fore-and-aft shearing stresses. These stresses were in turn largely relieved by projecting locking pieces, fitted on the top of the seating and in contact with each end of the thrust blocks.

Due to the vast size of *Titanic*'s engines, the thrust blocks associated with the reciprocating engines could not be located within the Reciprocating Engine Room as there was insufficient space within the Engine Room to accommodate the number of thrust collars the shaft required. Instead, they were located immediately aft of the watertight bulkhead separating the Reciprocating and Turbine Engine Rooms. As a result, it was not possible to position the thrust blocks with their forward ends abutting on the engine bedplates, a common arrangement that, when employed, distributed the forward thrust amongst the numerous holding-down bolts of the engine bedplates. Instead, the scantlings of the individual members forming the thrust seats were unusually heavy. Each thrust-block seating was formed of a thick horizontal plate supported by three fore-and-aft bearer plates (the latter being held erect by a cross plate at either end) and by intermediate diaphragm plates. It was important that the seats were long in their fore-and-aft dimension so that the thrust was distributed over a large portion of the vessel's framework, and to avoid any tendency to topple or trip. *Titanic*'s thrust seats were positioned over a series of six frames and included intercostal plates under the side bearers

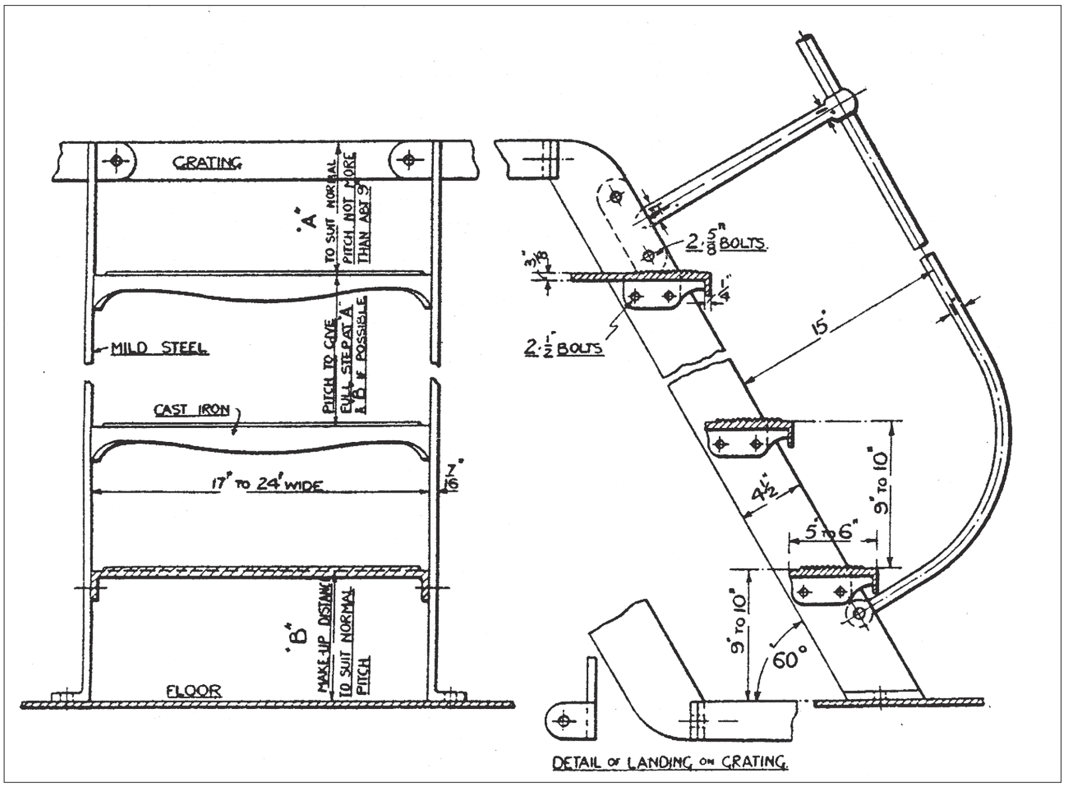
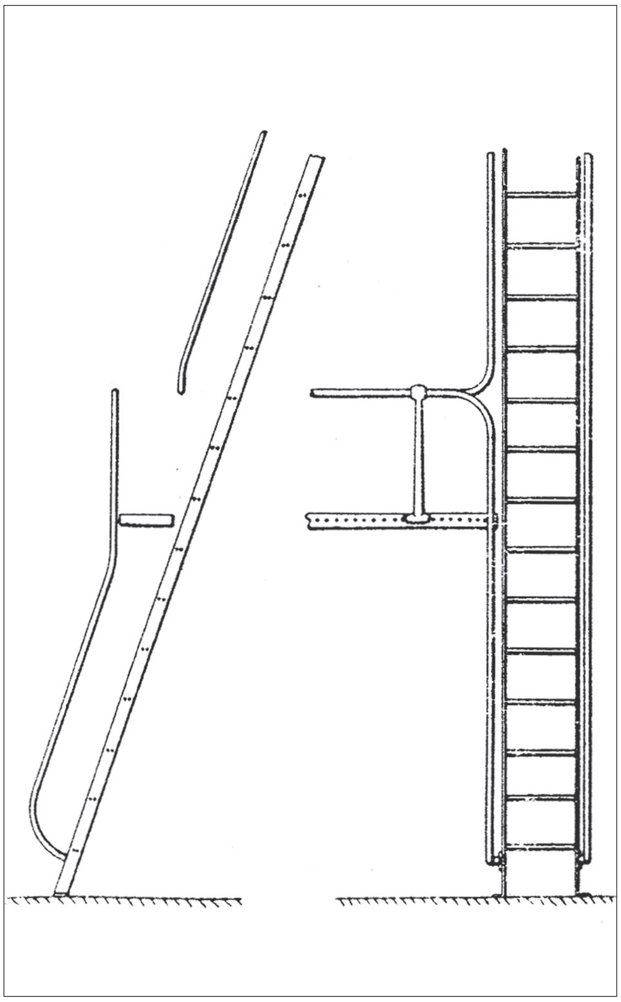
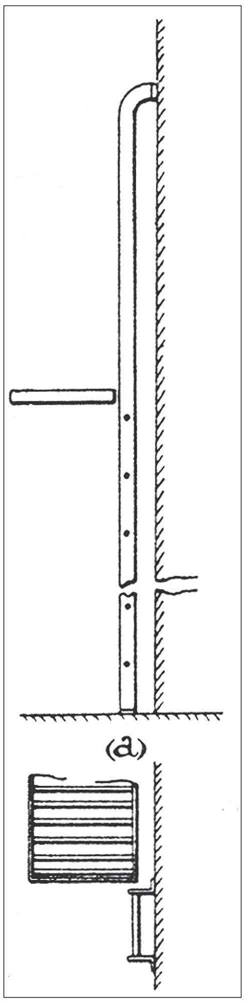

GRATING
'A'
TO SUIT NORMAL PITCH NOT MORE THAN ABT 9"
PITCH TO GIVE FULL STEP AT 'A' & 'B' IF POSSIBLE
MILD STEEL
CAST IRON
17" TO 24" WIDE
7/16"
'B'
MAKE-UP DISTANCE TO SUIT NORMAL PITCH
FLOOR
2-5/8" BOLTS
3/8"
1/4"
2-1/2" BOLTS
15"
9" TO 10"
4 1/2"
5" TO 6"
9" TO 10"
60°
DETAIL OF LANDING ON GRATING

Fig. 15-116
Ladder for Main Entrances – Ladders for main entrances were made fairly wide; this drawing shows such a ladder, giving a detail of the steps.



Left Fig. 15-117 **Steep Spill Ladder** – Steep spill ladder from a high platform to the floor. The ladder skirts an intermediate grating, and the ladder handrail branches along it.

Right Fig. 15-118 **Vertical or 'Jacob's' Ladder** – A typical vertical ladder; (a) is the plan view of this arrangement, and demonstrates the most common and safest position to place a landing in relation to a Jacob's ladder.



to thoroughly bind them to the floors. Straining of the thrust seats occasionally occurred as a result of a stormy voyage and perpetual racing of the engines; the only way to protect against this was by thorough and careful design and construction.

Propeller shaft stools

The thrust blocks, although absorbing the propeller's thrust, did not provide support for the shafts. Support for the propeller shafts was provided by bearings called 'plummer blocks' at intervals averaging 15ft. The plummer blocks were bolted to seats called 'shaft stools' or 'tunnel stools'. They not only supported the weight of the shaft, but also held it against any tendency to bend sideways under the longitudinal thrust. As the force brought about by longitudinal thrust was not as extreme as the fore-and-aft thrusts dealt with by the thrust blocks, the seating for the plummer blocks were lighter construction. With an inner fore-and-aft bearer added, the stools then formed a box; access to the interior of this box was gained through lightening holes.

Boiler stools

The boilers did not require the extensive seats constructed beneath the engines. Although very heavy, the boilers were inert dead weight. They sat in cradles called 'boiler bearers' or 'boiler stools' formed by a vertical plate, the upper edge of which was curved to the radius of the boiler shell. For a short single-ended boiler, two stools in the length were sufficient, while for a large double-ended one, four were necessary. The seatings for the boilers were heavily constructed to provide a large margin of strength. When full of water, a Scotch boiler was a very heavy mass as may be seen in the table of figures which accompanies the boiler portion of this chapter. Moreover, the weight of a boiler could be greatly augmented by the vertical movement of the vessel; in the case of the wing boilers, lying near the bilge, the added vertical oscillation due to rolling caused a still-further increase in effective weight. Also as a result of rolling, the entire weight of the boiler could be thrown against the upper part of the stools on one side where, owing to their greater height, they were less capable of supporting it. To provide against the effect of excessive rolling, round iron stays were led diagonally from the tops of the outermost boilers to the stringer plates of the Orlop keelsons at the vessel's side; the intermediate boilers were then stayed to the outboard boilers and to one another.

The boiler stools sat directly on the Tank Top plates. Wrought iron was used in their construction, and the plates which were generally ¾in thick, were stiffened all around by large double angles. Each stool was made in two sections which were symmetrical about the centerline of the boiler; this made them easier to install, and also allowed them to fit the boiler better as well. To allow for expansion through heating and cooling, the boilers were not physically attached to the stools; they merely rested on them, the curved form of the stools preventing any transverse movement.

Fore-and-aft movement had to be guarded against as well. The momentum of a heavy boiler when a vessel's motion was suddenly arrested (as in the event of an end-on collision) could cause the boilers to jump forward, which could in turn result in fracturing of the steam pipes. To prevent this, collision chocks (called 'ramming chocks' in warships) were fitted. These were simple vertical brackets fitted to the Tank Top, and were formed of thick wrought-iron plate stiffened by double angles. They were useful not only in preventing the displacement of the boilers in the event of a collision, but also in preventing the gradual fore-and-aft 'creeping' movement which would otherwise occur over time from continued expansion and contraction. For each of the single-ended boilers, one chock was fitted at each end of the boiler, the upper corners of which overlapped the faces of the boilers. The chocks for the double-ended boilers were fitted completely beneath each boiler, and were designed to bear against the inner edges of the two outside strakes of the boiler shell.

To prevent tripping of the stools, they were supported by fore-and-aft brackets. For the double-ended boilers, the end brackets of the paired stools at one end were designed to unite these stools, further staying the supports beneath the heaviest boilers against the effects of the pitching of the ship. The end plates of these paired stools were made with a cut-away, curved upper edge to allow proper ventilation beneath the boilers.

The cellular bottom tank framework in the boiler room was also increased in strength, with the floors that the boiler bearers rested upon being provided with double reverse bars. In most ships, the thickness of the floors, and that of all other parts of the tank beneath the stools, was increased by 0.04 to 0.10in above those employed elsewhere. This increased thickness was intended to serve as an extra margin against corrosion resulting from the harsh environment found in marine boiler rooms. However, due to the unusually heavy scantlings of the double bottom members employed in the construction of the *Olympic*-class liners, no increase in thickness of these components was deemed necessary.

Because most of *Titanic*'s boilers were placed outboard of the centerline of the ship, they could not be lowered directly into their berths. In the fitting-out photos, it will be noted that the boilers were not always positioned upright in the lifting slings; instead they were placed in the slings in an orientation which would result in the boilers being turned upright after they had been rolled the required distances to reach their berths from the centerline of the ship. Once positioned accordingly in their slings, the boilers were then lowered straight down through the central deck openings, and then rolled athwartships on heavy timber and iron staging erected to clear the boiler stools. Once each boiler was in position over the stools and approximately upright, it was raised slightly to clear the staging. The staging was then removed from beneath, allowing the shipwrights to lower the boiler onto the stools.

MOBILITY THROUGHOUT THE BOILER AND MACHINERY SPACES

Boiler and machinery space raised decks

A raised deck was provided throughout the machinery and boiler spaces. This was necessary so that the engineers and firemen could stand at a convenient height in relation to both the machinery and the boiler furnaces while performing their work. Additionally, and of equal importance, the raised decks provided a clear passageway through the stokeholds and machinery spaces through which to run the ballast and bilge piping, which was located immediately above the Tank Top plates, while providing an unobstructed walkway for the firemen and engineers. The top surface of this decking was 2ft 7½in above the Tank Top level in most compartments. However, due both the height of the engine bedplates and large quantity of piping beneath the deck plates within the main engine rooms, this height was increased. In portions of the Turbine Engine Room, the top surface of the raise decking was 4ft above the Tank Top plating, while the height of the deck plates was set at 5ft throughout the Reciprocating Engine Room. The supporting framework of these raised decks was ruggedly constructed with angle and tee bars. The surface of the deck was comprised of small chequered plates so that these could be readily lifted to gain access to the pipes lying below and to clean the bilge spaces. The plates formed a continuous surface, without crevices; this was of particular importance in the boiler rooms, so that small coal and ashes could not pass below to form a slurry with the bilge water and choke the pumps.

Access to the higher levels

Gratings and ladders were heavily used within the working spaces of ships. *Titanic*'s wreck has revealed many such examples strewn across the seabed as a result of her hull breaking through the Reciprocating Engine Room and casing. Gratings and ladders were used extensively in the machinery and boiler spaces. The locations of the gratings – often called 'catwalks' – and the ladders which provided access to them and to the upper levels of the casings were too extensive to discuss individually, but they will be addressed here in general terms to familiarize the reader with their importance. (It should be noted that in shipboard nomenclature, 'ladder' can refer to a vertical ladder with rungs, but more commonly – as in the context here – it refers to what most people would, on land, refer to as a set of stairs.)

Gratings

Gratings could be any width, according to their location and their intended use. Grating platforms were carried by brackets from the cylinders, engine columns, and casing sides. A width of 2ft was satisfactory for a main passage, but only 16 or 18in was possible in many places. Ideally, nothing less than 16in was generally used, although at times only 14 or even 12in could be secured. If over 2ft wide, a longitudinal stringer was to be introduced to afford support for the bearing bars, or 'spills'. Where a grating was accessed directly from one of the decks, rather than up or down a ladder, the grating was to be at the same level as the deck, for ease in stepping through the door.

Support brackets could have been cast-iron, or composed of simple steel bars 2¼in x ¾in bent to shape, and would have had stops, or clips, to prevent the platform from moving. Gratings were made in as few pieces as possible, but at the same time were made neither too heavy nor too large for erection; 20ft long was generally considered the maximum. Long lengths carried by brackets were to have the joints in the neighborhood of the brackets and not midway between them, otherwise sagging to an unwanted degree would result. Gratings and platforms also had to be of sufficiently sturdy construction – if made too light, they would buckle or become distorted with the loads sometimes dropped on them. Round spills were generally employed, as square and T-shaped spills were not popular with engineers, because the sharp edges on these types of spills had a tendency to cut up the soles of their boots.

Main-way gratings were composed of mild-steel spills of ⅜or ¾in diameter and 2¼ or 2½in pitch; ⅜in spars were quite satisfactory if used. The side bars carrying them would generally be 2¼in x ⅜in. Gratings of 'firebar' section – trapezoidal in section and wider at the top – were sometimes asked for in cylinder and entrance platforms. Around the reciprocating engine cylinders and at similar places, the gratings were to be 1½in clear of whatever surface they skirted. Platform brackets and bars were not to be bolted rigidly between the ship and vibrating parts like cylinders; one end was required to be free to slide in a slot bracket. T-bars, resting in slot brackets, were employed to carry the grating between twin engine cylinders. Platforms around turbines, when employed, were fastened to the seatings.

Gratings of secondary importance, like those for convenience of painting, would have spills 9/16 or ⅜in in diameter and side bars 2¼in x ⅜in. For water-gauge platforms above the boilers (the mid-level platforms located immediately above each stokehold, providing direct access for reading and/or servicing the water-level gauges), the gratings were made as heavy as the engine room platforms; on the boiler tops the gratings were made lighter, usually the same as those for the engine casing. Fidley gratings were, however, of the heavy design.

Water-gauge platforms were supported by bars carried in slot brackets bolted to the smokebox front and to the bulkhead, being fastened to one and sliding in the other; the bars had ½in end clearance for expansion. Boiler top gratings were clipped to securing stays and cleading irons. Engine casing platforms were carried by plate or cast brackets, triangular bracing, or any suitably-shaped carrier from the casing side of local structural work. If a cross-grating was to be carried by a bar, the latter was made to coincide with one side stringer of the grating; the other side was unsupported. Extended handrail pillars or balusters to decks above were avoided unless no alternative was possible. Casing gratings were made on the assumption that the local load would not exceed the weight of two men. To prevent the heavy vibration of casing handrails in service, hooks, swinging on the handrails, could be attached to eyelets on the casing side.

The greasing platform along the front of the engine was sometimes made of chequered plating carried in side bars, in preference to spilled grating, to prevent debris falling onto the operating Engineers. For a similar reason main ladders had their undersides sheathed with light iron sheeting. Over the main bearings, pieces of chequered plate were introduced in the greasing platform; these plates could be lifted when overhauling the engines, when pulley blocks for lifting the bearing keeps were hung from the cylinder bottoms. This allowed the lifting tackle to run straight down through the now-opened platform framework.

Since the intermediate shafts ran at a considerable height above the Tank Top, platforms of gratings were fitted alongside the shafts within the machinery spaces and shaft tunnels at a suitable height which permitted the Greasers to walk the length of each shaft while monitoring and tending to the shaft bearings. In addition to the gratings, because the tunnels were often awash with the water used in cooling the bearings, raised flooring was required in these spaces as well.

Handrails were necessary on all gratings. They were made not less than ⅜in in diameter, this being not for strength, but for ease of grip; the pitch of the stanchions carrying them was usually about 6ft. On boiler tops there was a handrail at one side of the grating only. Single handrails were used for most purposes, with a fender or toe-plate where the grating skirted unprotected mechanisms. Double handrails or single rails with a toe-plate round the grating were sometimes asked for high up in the Engine Room, to prevent accidents when the ship pitched or rolled suddenly. Yet most ships had no more protection than a single handrail, without the toe-plate.

As far as possible, gratings were to be completed from the drawings, and then trial-erected on the engines and boilers in the shop, but, since many dimensions depended on numerous factors, many of which could not be accurately determined prior to assembly of the machinery aboard the ship, there were always a number of gratings which had to be made from templates. The above comments also applied in regard to ladders. Pieces the draftsmen intended to have made from templates were indicated clearly on drawings.

Gratings had to have enough headroom above them to enable a man to move about without difficulty. A similar requirement applied to ladders, bearing in mind that the body of a man ascending a ladder is vertical. A clear height of 6ft 6in was aimed for in the engine-room, but 4ft 6in was considered acceptable on a boiler top. Gratings and ladders had to be designed to clear lifting and traveling gear, strong beams, ventilators, and the like.

Ladders

The scheme of main ladders was generally worked out when the general arrangement of the machinery was underway, to avoid subsequent complications. Unnecessary steps were to be avoided, and all gratings in the same neighborhood were arranged at the same level wherever possible. Nothing fatigued a man and wore him out more than having continuously to run up and down from one level to another.

Ladders for main entrances were made fairly wide, in general from 21 to 24in, with cast-iron steps of 9 to 10in vertical pitch. The treads of the steps were designed to enable the dirt to be easily brushed out of the grooves. The top step was made broader than the others. Ladders of this description were generally designed to have an incline of about 60°, with 68° being considered the maximum. With this inclination and pitch of step, a person could descend the ladder looking in the direction of the motion, but if made steeper, the effective foothold was lessened and sooner or later, someone was likely to wind up falling headlong down the ladder. For this reason many sea-going engineers instinctively turned around and faced the ladder as they descended it.

The sidebars of ladders had to be carried at least 4ft above the grating level to act as handrails, otherwise short handrails secured to the bulkhead were fitted. It was the general practice to introduce chequered plating on gratings at ladder landings, or, if the grating was spilled where a ladder joined it, a canvas bag or mat could be thrown over the grating should there be any tendency to slip.

For ladders not in constant use, the spill construction was generally used; double rungs of ⅜, 11/16, or ¾in-spills with 9 to 11in vertical pitch were general practice, carried in 3in x ⅜in or 3½in x 7/16in side bars. These ladders were somewhat steeper than main-way ladders; an angle of 70° was common, with 80° or even 83° being employed in very tight places in the stokehold. They were not generally bolted to the floor in stokeholds. Where there was a handrail at each side, ladders were not to be less than 16in in width; 16 and 18in were common. Sloping ladders had been made up to 19ft long, but only when it was possible to fasten one side bar to a bulkhead. Where there was no room for a sloping ladder, or if it was only for emergency use, a vertical ladder was generally used, built of ⅜or ¾in single spars of about 12in vertical pitch, with 1¾in x ⅜in or 2½in x ⅜in side bars, and 12 or 14in wide. This form was universally referred to as a 'Jacob's ladder', though how this term became associated with ladders aboard ship is not clear.

Notes

1. Tabular fuel consumption figures compiled from the following sources:

The Shipbuilder, Vol. 7, Midsummer 1911 Special Number, 'The White Star Liners *Olympic* and *Titanic*' (reprint; Patrick Stephens Ltd, 1970)

Griffiths, Dr. Denis, *Power of the Great Liners* (Patrick Stephens Ltd, 1990)

Baker, G. S., *Ship Form, Resistance and Screw Propulsion* (D.Van Nostrand Co., 1915)

2. Calculation based upon data obtained regarding coal consumption and IHP figures at given speeds for *Laurentic* and *Olympic*.
3. Griffiths, *Power of the Great Liners*, p. 88.
4. Griffiths, *Power of the Great Liners*, pp. 90-91.
5. Dunn, Laurence, *Famous Liners of the Past, Belfast Built* (Adlard Coles Ltd, 1964) p. 200.
6. Griffiths, *Power of the Great Liners*, p. 123.
7. Griffiths, *Power of the Great Liners*, pp. 93-96.
8. Moss, M., & Hume, J.R., *Shipbuilders to the World* (The Blackstaff Press, 1986) pp. 133-134.
9. Dunn, Laurence, *Famous Liners of the Past, Belfast Built*, p. 204.
10. Moss, M., & Hume, J.R., *Shipbuilders*, p. 129.
11. Parsons, Sir Charles, *The Steam Turbine*. (Cambridge University Press, 1911)
12. Moss, M. & Hume, J.R., *Shipbuilders*, pp. 133-135.
13. Moss, M. & Hume, J.R., *Shipbuilders*, p. 144.
14. Harland & Wolff Archives, *Particulars of Ships*, entries for Nos 400 and 401.
15. McCaughan, Michael, *Birth of the Titanic*, drawing 'Design 'D', reproduced in endpapers.
16. Griffiths, *Power of the Great Liners*, p. 104.
17. Harland & Wolff Archives, *Particulars of Ships*, entries for Nos 400 and 401.
18. Titanic Historical Society, Inc., *The Titanic Commutator, April 1976, vol. II no.IX.*
19. Per Mark Chirnside, calculations based primarily upon data obtained from the Public Records Office, London.
20. From this point forward, this chapter is based largely on information gathered from the following sources:

The Shipbuilder, Vol. 7, Midsummer 1911 Special Number, 'The White Star Liners *Olympic* and *Titanic*' (reprint; Patrick Stephens Ltd, 1970)

Engineering, vols. 89, 90, 91, 94

The Engineer, vols. 109, 110, 117

S.S.400 Specifications notebook, Drawing Office Copy (Harland & Wolff Ltd, Belfast, *c.*1908-1913)

Holmes, A. Campbell, *Practical Shipbuilding* (Longmans, Green and Co, London, 3rd ed. 1918)

Pounder, C.C., *Machinery and Pipe Arrangement on Shipboard* (Emmott & Co. Ltd, Manchester, 1922)

Sennett, R., & Oram, H.J., *The Marine Steam Engine* (Longmans & Co., London, 11th edition 1913)

Sothern, J.W.M., *Verbal Notes and Sketches for Marine Engineers* (James Munro & Co. Ltd, Glasgow, 7th ed. 1911)

Sothern, J.W.M., *The Marine Steam Turbine* (James Munro & Co. Ltd, Glasgow, 6th ed. 1919)

MacGibbon, W.C., *Board of Trade Orals and Marine Engineering Knowledge, Steam and Diesel* (James Munro & Co. Ltd, Glasgow, 10th ed. 1938).

21. These figures represent the weight of water in the boilers when completely filled for hydrostatic pressure testing; the weight of water in the boilers when filled to the correct level for steam production would be approximately 30 per cent less.
22. In 2007, *Olympic* researcher Mark Chirnside discovered an Engineering Office notebook from Harland & Wolff that specified the center propeller as being three-bladed and not four-bladed, with a diameter of 17ft , a pitch of 14ft 6in and a surface area of 120sq.ft. This handwritten notebook, listing propeller specifications and engine details by yard number, also gave a slightly differing pitch for the wing propellers, with the figure of 34ft 6in crossed out and rewritten as 35ft. Prior to this it had always been assumed that *Titanic*'s center propeller matched *Olympic*'s in number of blades. At the time of this writing, however, no photographs are known to exist of *Titanic*'s propellers after being fitted. However, it is known that *Olympic*'s four-bladed center propeller was replaced with a three-bladed one during her extensive refit in 1912-13, so *Titanic* may well have been similarly fitted. Steamship companies and shipbuilders were constantly seeking to reduce vibration and improve performance, so changes in propeller size and pitch were not uncommon.
23. Increased to 34ft 6in in November of 1911 during repairs following collision with HMS *Hawke*.

Chapter 16

Water Systems, Ballast and Bilge Arrangements

An empty ship, riding high out of water with its center of gravity well above the water line, is top-heavy, unstable and liable to capsize in a storm. A vessel in such a condition is also subject to a far greater influence from the wind and therefore difficult to steer and likely to be driven off its course in rough weather. For these reasons, the practice has always been to bring an unloaded ship farther down into the water by placing some heavy material, known as 'ballast', in the bottom of its holds.

For centuries, ballast consisted of dirt, sand, gravel or stones, taken from the shores of the harbor where the ship unloaded its cargo. This caused serious delays at both ends of the route, because this type of ballast could not be put aboard until after the cargo had been off-loaded and it then had to be removed before a return cargo could be brought onboard. It was also undesirable from the standpoint of expense, as wages had to be paid for handling ballast with no revenue earned for carrying it.

Around 1885, the carriage of water ballast in iron and steel ships was made possible through the introduction of the 'McIntyre tank'. This tank was formed in the bottom of the ship by a watertight plate cover built above the floors[1] of a single-bottom ship and supported by fore-and-aft girders riding on the tops of the floors. Into the space created, water ballast could be pumped to give the vessel sufficient draft when light. Since this water could be handled by the ship's own pumps and pumped out or in without waiting for the ship to be loaded or unloaded, the delay and expense associated with the use of other types of ballast were eliminated. In addition, the amount of ballast could be increased as necessary at sea to compensate for the gradual lightening of the ship from the expenditure of fuel that would occur over the course of the voyage.

In large ships, the volume of water contained in a double bottom of the usual depth was insufficient to immerse the vessel properly when light. As increasing the height of the double bottom to correct this problem was not feasible (it would prohibit space for machinery and cargo), it was decided to carry extra water ballast in 'deep tanks'. These deep tanks, located at the bow and the stern, were respectively termed 'fore peak' and 'after peak' tanks. Besides supplementing the tanks within the double bottom for the purposes of bringing the vessel farther down in the water, their location at the extreme ends of the vessel meant they could be used as trimming tanks. The peak tanks permitted adjustments to secure an even keel if the cargo stowage or consumption of coal during the voyage caused an undesirable trim, to increase the immersion of the propellers if the vessel was light, or secure a smaller draft when entering a shallow harbor or dock.

Double-bottom tanks

Ballast tanks were always kept as full as possible; however, when used as a reservoir for fresh water, a semi-filled condition was as common as a full one. Accordingly, tanks intended for this purpose were kept relatively small. The water within a partially filled tank tends to move about in response to the motion of the ship. This is called 'heeling effect' or 'free surface effect'. It is strongest with a tank that is half filled. The motion of the water can be reduced to some extent by vertical steel plates within each tank, the vertical plates pierced with holes to allow the water to equalize throughout the tank. However, while this checks the momentum of the water's movement, it does not prevent the shifting of the entire mass of water from one side to another. On a ship, if a large ballast tank were constructed across the full width of the ship, the mass of tens of thousands of gallons heeling from one side to another might cause excessive rolling or even put the ship at risk in heavy weather. But water in smaller quantities, and especially in tanks constructed across only part of the bottom, is less likely to develop any serious momentum and its heeling effect is small. For this reason *Titanic*'s double bottom was constructed with numerous smaller tanks rather than a lesser number of larger ones. The floors and longitudinal stiffening plates within, in addition to providing structural integrity, formed both the sides and the interior baffles of the individual tanks. Those forming the sides of the tanks,

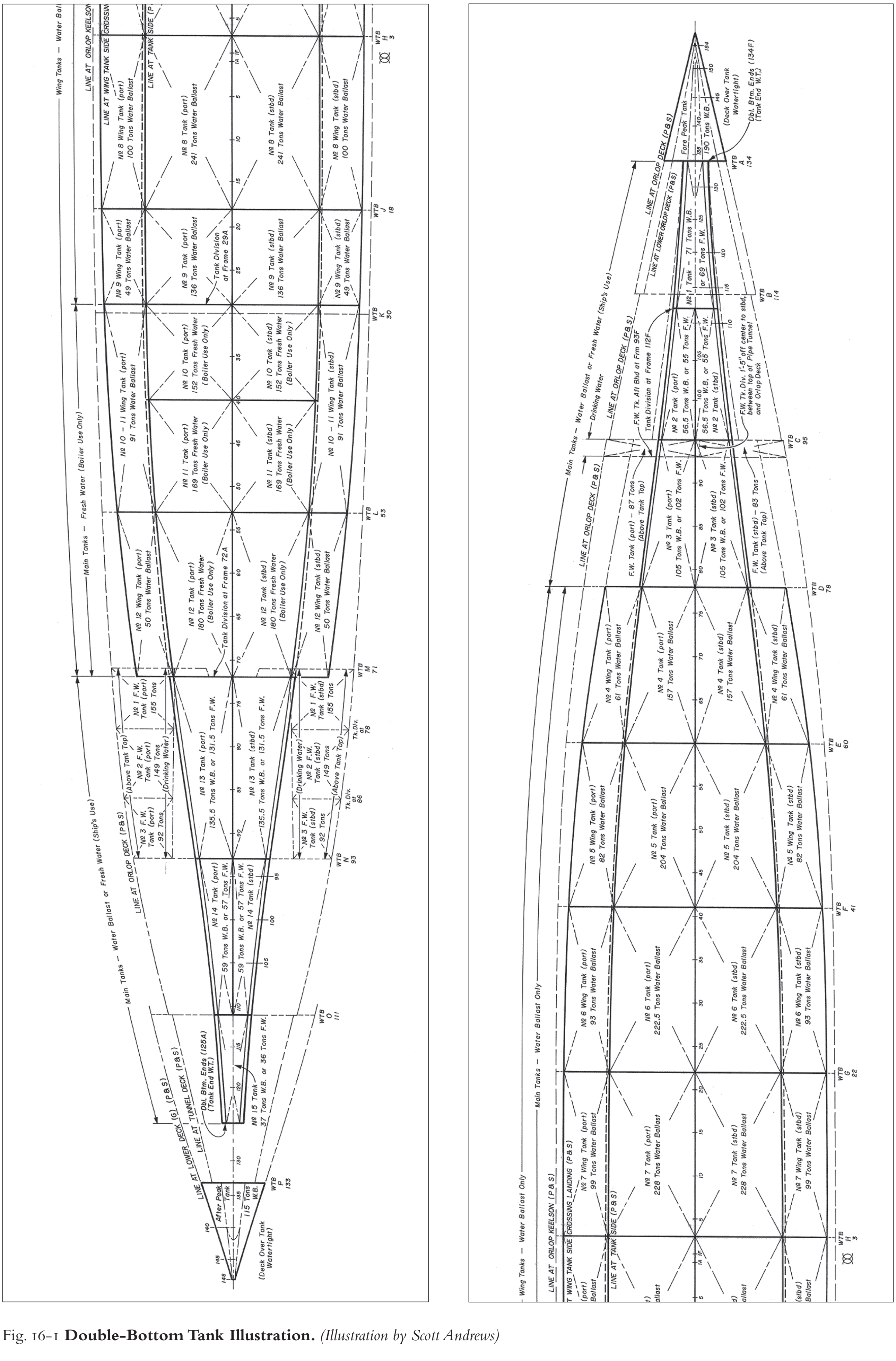

Wing Tanks — Water Ballast
LINE AT ORLOP KEELSON
LINE AT WING TANK SIDE CROSSING
LINE AT TANK SIDE
Nº 8 Wing Tank (port) 100 Tons Water Ballast
Nº 8 Tank (port) 241 Tons Water Ballast
Nº 8 Tank (stbd) 241 Tons Water Ballast
Nº 8 Wing Tank (stbd) 100 Tons Water Ballast
WTB H 3
Nº 9 Wing Tank (port) 49 Tons Water Ballast
Nº 9 Tank (port) 136 Tons Water Ballast
Tank Division at Frame 29A
Nº 9 Tank (stbd) 136 Tons Water Ballast
Nº 9 Wing Tank (stbd) 49 Tons Water Ballast
WTB J 18
Main Tanks — Fresh Water (Boiler Use Only)
Nº 10 – 11 Wing Tank (port) 91 Tons Water Ballast
Nº 10 Tank (port) 152 Tons Fresh Water (Boiler Use Only)
Nº 10 Tank (stbd) 152 Tons Fresh Water (Boiler Use Only)
Nº 10 – 11 Wing Tank (stbd) 91 Tons Water Ballast
WTB K 30
Nº 11 Tank (port) 169 Tons Fresh Water (Boiler Use Only)
Nº 11 Tank (stbd) 169 Tons Fresh Water (Boiler Use Only)
WTB L 53
Nº 12 Wing Tank (port) 50 Tons Water Ballast
Nº 12 Tank (port) 180 Tons Fresh Water (Boiler Use Only)
Tank Division at Frame 72A
Nº 12 Tank (stbd) 180 Tons Fresh Water (Boiler Use Only)
Nº 12 Wing Tank (stbd) 50 Tons Water Ballast
WTB M 71
Main Tanks — Water Ballast or Fresh Water (Ship's Use)
LINE AT ORLOP DECK (P&S)
Nº 1 F.W. Tank (port) 155 Tons
Nº 2 F.W. Tank (port) 149 Tons (Above Tank Top) (Drinking Water)
Nº 3 F.W. Tank (port) 92 Tons
Nº 13 Tank (port) 135.5 Tons W.B. or 131.5 Tons F.W.
Nº 13 Tank (stbd) 135.5 Tons W.B. or 131.5 Tons F.W.
Nº 1 F.W. Tank (stbd) 155 Tons
Nº 2 F.W. Tank (stbd) 149 Tons (Drinking Water) (Above Tank Top)
Nº 3 F.W. Tank (stbd) 92 Tons
Tk. Div. at 78
Tk. Div. at 86
WTB N 93
Nº 14 Tank (port) 59 Tons W.B. or 57 Tons F.W.
Nº 14 Tank (stbd) 59 Tons W.B. or 57 Tons F.W.
WTB O 111
LINE AT LOWER DECK (G) (P&S)
LINE AT TUNNEL DECK (G) (P&S)
Dbl. Btm. Ends (125A) (Tank End W.T.)
Nº 15 Tank 37 Tons W.B. or 36 Tons F.W.
After Peak Tank 115 Tons W.B.
WTB P 133
(Deck Over Tank Watertight)
Wing Tanks — Water Ballast Only
LINE AT ORLOP KEELSON (P&S)
LINE AT WING TANK SIDE CROSSING LANDING (P&S)
LINE AT TANK SIDE (P&S)
Main Tanks — Water Ballast Only
Nº 7 Wing Tank (port) 99 Tons Water Ballast
Nº 7 Tank (port) 228 Tons Water Ballast
Nº 7 Tank (stbd) 228 Tons Water Ballast
Nº 7 Wing Tank (stbd) 99 Tons Water Ballast
WTB H 3
WTB G 22
Nº 6 Wing Tank (port) 93 Tons Water Ballast
Nº 6 Tank (port) 222.5 Tons Water Ballast
Nº 6 Tank (stbd) 222.5 Tons Water Ballast
Nº 6 Wing Tank (stbd) 93 Tons Water Ballast
WTB F 41
Nº 5 Wing Tank (port) 82 Tons Water Ballast
Nº 5 Tank (port) 204 Tons Water Ballast
Nº 5 Tank (stbd) 204 Tons Water Ballast
Nº 5 Wing Tank (stbd) 82 Tons Water Ballast
WTB E 60
Nº 4 Wing Tank (port) 61 Tons Water Ballast
Nº 4 Tank (port) 157 Tons Water Ballast
Nº 4 Tank (stbd) 157 Tons Water Ballast
Nº 4 Wing Tank (stbd) 61 Tons Water Ballast
WTB D 78
Main Tanks — Water Ballast or Fresh Water (Ship's Use)
LINE AT ORLOP DECK (P&S)
F.W. Tank (port) – 87 Tons (Above Tank Top)
Nº 3 Tank (port) 105 Tons W.B. or 102 Tons F.W.
Nº 3 Tank (stbd) 105 Tons W.B. or 102 Tons F.W.
F.W. Tank (stbd) – 83 Tons (Above Tank Top)
WTB C 95
Drinking Water
F.W. Tk. Aft Bhd at Frm 93F
Tank Division at Frame 112F
Nº 2 Tank (port) 56.5 Tons W.B. or 55 Tons F.W.
Nº 2 Tank (stbd) 56.5 Tons W.B. or 55 Tons F.W.
F.W. Tk. Div. 1'-5" off center to stbd, between top of Pipe Tunnel and Orlop Deck
WTB B 114
Nº 1 Tank – 71 Tons W.B. or 69 Tons F.W.
LINE AT LOWER ORLOP DECK (P&S)
LINE AT ORLOP DECK (P&S)
Fore Peak Tank – 190 Tons W.B.
WTB A 134
Dbl. Btm. Ends (134F) (Tank End W.T.)
(Deck Over Tank Watertight)

Fig. 16-1 **Double-Bottom Tank Illustration.** *(Illustration by Scott Andrews)*

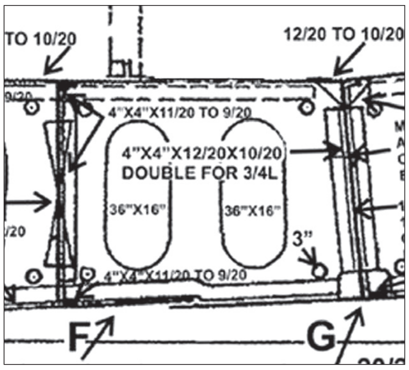


Fig. 16-2 **Limber and Lightening Holes** – This enlarged detail from the Midship Section shows the lightening and 3in-diameter limber holes in *Titanic*'s double bottom floors.

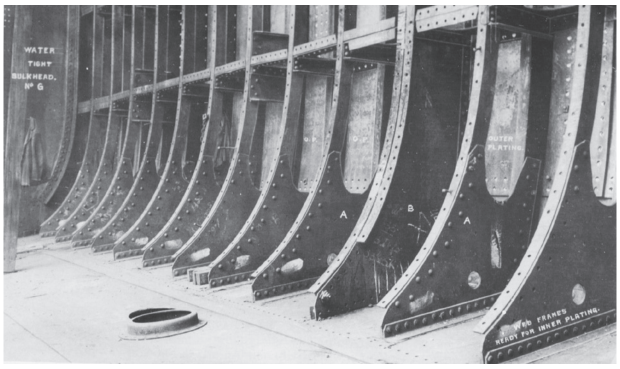

WATER TIGHT BULKHEAD. No 6
OUTER PLATING
WEB FRAMES READY FOR INNER PLATING.

Fig. 16-3 **Manhole on *Britannic*** – A view along *Britannic*'s inner bottom plating at WTB G, showing the installation of her inner skin framing. At the Tank Top level can be seen a coaming for a manhole. *(*Engineering*/Authors' collection)*

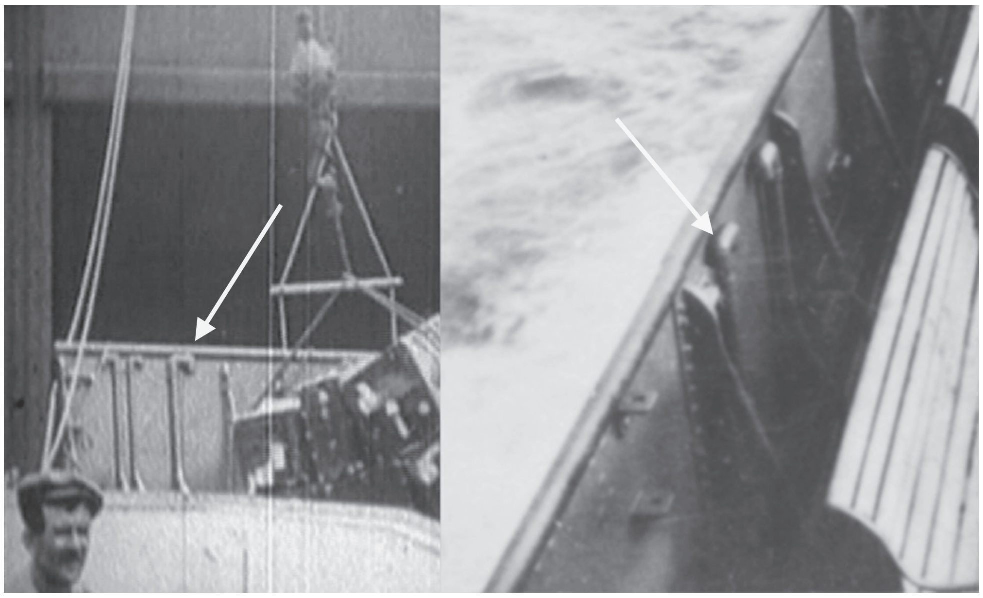


Fig. 16-4 **Well Deck Air Vents** – At left, *Olympic*'s forward Well Deck; at right, the after Well Deck. Located along the insides of the bulwarks were ventilation pipes from some of the double-bottom tanks below. Though most of these vents ended just above the bulkhead deck, others were brought to the height of the weather decks as seen here. *(Left image authors' collection; right image Peter Davies-Garner collection)*

as well as the keel, were made watertight through the caulking of the top and bottom angles and the omission of limber and air holes. *Titanic*'s cellular double bottom was divided into forty-four compartments; the addition of the Fore and After Peak Tanks resulted in a total of forty-six. Six of these tank compartments (those within the margin plates beneath the two engine rooms) were used exclusively for fresh water for boiler feed make-up purposes. The wing tanks outboard of these and all of the tanks under the boiler spaces, as well as the Fore and After Peak Tanks, were reserved for salt-water ballast only.[2] The remainder of the tanks within the double bottom could be filled with either salt or fresh water. Each of these compartments had pipe suctions connected through a main pipe to the ballast pumps. Specifically, fourteen of these compartments had 8in suctions, twenty-eight had 6in suctions and three had 5in suctions connected to the 10in ballast main suction. The total amount of water ballast that could be carried by *Titanic* (including feed-water stores) was 5,754 tons, of which 190 tons were in the Fore Peak Tank and 115 tons in the After Peak Tank.

Manholes were provided in the Tank Top for access to the double bottom and were provided to form an inlet and outlet to encourage proper circulation of air when work was being done in the tank. A manhole was placed near each end of each fore-and-aft space bounded by side girders, so that a man making an inspection of the tank could pass from end to end of each space, missing no part and without having to retrace his steps.

As noted above, the floors and longitudinals were perforated with lightening or limber holes so that when the tanks were filled or pumped out, the water could flow from cell to cell. Limber holes were provided in the lower margins of the floors and longitudinals as were drain holes flush with the surface of the cement coatings. The entrance of water also involved the exit of the same volume of air and so additional provision was made for the passage of the latter from cell to cell so that it could find its way to the air pipes provided for its escape. (These are discussed later, under Ballast Systems.) The necessary air passages were provided in the upper parts of the floors and longitudinals so that when the water rose above the lightening holes, the air would still have ample means of escape and not check the rise of the water and the complete filling of the tank. For this purpose, holes were provided in the upper margins of the floor plates so that when cleaning or repair work was being done in the tank, the hot fume-laden air could flow readily from cell to cell to escape through the manholes in the Tank Top.

Ballast systems

The ballast suctions were led over the Tank Top and passed down within the tanks where required. In the large flat-bottomed tanks, middle-line and side suctions were fitted. The latter were for emptying the tank when the vessel had a list since, as the amount of water in the tank decreased during pumping, it tended to flow to one side and heel the ship. Regarded as auxiliaries, the side suctions were usually of smaller diameter than the middle-line suctions. In the tanks divided by a fore-and-aft central division, a suction was fitted in each half. Usually two or more valve chests were provided for the forward and after tanks, which permitted one set of tanks to be filled while the other was being emptied.

Five vertical duplex Harland & Wolff ballast pumps having 11in-diameter steam cylinders, 12in-diameter pump barrels and a 15in stroke were arranged to draw water in from the 10in main ballast pipe connected to the condenser intakes. This main was carried fore and aft through the ship with separate connections to each tank. Each pump was capable of discharging 250 tons of water per hour. To ensure that water was not inadvertently admitted into unwanted areas, separate valve chests were provided for the bilges and the ballast tanks, as well as separate valves for flooding the tanks and discharging ballast. When required to empty water from the ballast tanks, the same mains utilized for discharging bilge water were used. Two ballast pumps were placed in the Reciprocating Engine Room with large suctions from the bilges direct and from the bilge main.

In order that the ballast tanks could be completely filled, provision was made for the escape of the contained air as previously noted. For this purpose, air pipes were led from the Tank Top to a deck above where any overflow would do no harm. These terminated at a level above the Upper Deck (generally C or D Deck). In fact, there were air vent pipes present in the waterways of the forward and after Well Decks and the Poop Deck. In all cases, the air vent pipes were galvanized and to be no less then 2ft 6in in height.

The air pipes were left permanently open to avoid the serious damage that could occur through neglecting to uncap these pipes before attempting to fill or empty the tanks. Cases had occurred where a Tank Top had actually burst under the excessive hydrostatic pressure of the pumps. Similarly, in emptying the tank, if the air pipes were closed, a vacuum would be formed within the tank tending to collapse the top.

Sounding tubes, or wells as they are sometimes called, were fitted to all peaks and ballast tanks for the purpose of ascertaining the depth of water in the compartments. These pipes would sometimes extend to an upper deck protected from the weather, however a good majority of them terminated above the bulkhead deck and were sealed with brass caps. Soundings were periodically taken at sea by passing a rod 3 to 4ft long with a cord attached down the pipe and, on its withdrawal, noting how much of its length was wet.

The wells were to be sounded at least every six hours, and ballast and fresh water tanks at 6.00 a.m. and 6.00 p.m. by the Carpenter, accompanied at least once a day by a Junior Officer. The Carpenter was required to make a record of the soundings with a copy given to the Chief Officer, and recorded as well on the Engine Room sounding board. The Chief Officer would pass to the Chief Engineer the Carpenter's record of soundings after entering them in the Soundings Book or his Log Book and submit it to the Captain at 8.00 a.m. and 8.00 p.m. for his inspection and signature.

In order that the Engineer whose duty it was to fill and empty the tanks would know when they were full without going on deck to take soundings, the sounding pipes of the tanks abaft the boiler rooms terminated within the machinery spaces and tunnels, where a small tell-tale pipe was led from each tank. Each pipe terminated at a cock just above the platforms so that, when opened, an outflow of water would provide indication the tank was full.

When it was required to clean the bilges, inspect the cement or examine the tanks, it became necessary to remove all water from the tanks. This was done in drydock. Screwed plugs were fitted in the exterior shell plating of the hull along the garboard strake, one at the after end of each tank, hold or drain well. Upon removing the plugs, all the water was able to flow out. These drainhole plugs were brass, well greased and coated on the outside with paint. In order to provide extra strength around the plugs, a small doubling plate on the shell was fitted to give the plug an ample grip in the plating.

Bilge water

A well-built steel ship was usually quite watertight. However, there was always a possibility of water entering, for she could spring a leak through starting of the seams and riveting of the shell, due either to straining in heavy weather or to striking a submerged object; and volumes of water could pour through the hatchways or other deck openings if these were ill-secured in heavy weather. Pumps were provided to clear away the water, not only for the safety of the ship but to avoid the damage which cargo could suffer should even a small volume of water wash about at the bottom of a hold.

In steamships, water always tended to accumulate in the machinery compartments through leakage from the various drain cocks, pumps and tanks, and the constant flow into the bilges of water used for cooling the bearings and extinguishing the hot ashes in the stokeholds. To clear this away, steam bilge pumps were kept more or less constantly in operation. In heavy weather, the machinery compartments were also at risk from downflows of sea water through the fidley gratings and ventilators that were kept open to supply air to the furnaces and to ventilate the hot spaces below. (To protect against this, the machinery openings were raised well above the Boat Deck.)

If a large volume of water was allowed to accumulate in the bilges of the machinery spaces, the result could be serious. It could, in washing from side to side, lift the stokehold plates and throw them about, endangering the pipes and valves located beneath, to say nothing of the danger posed to the men standing on these plates. The water could also, by washing coal and ashes from stokehold into the bilges, result in the choking of the pumps and, with these inoperative, the water would continue to accumulate, eventually extinguishing the fires and placing the ship at risk. To avoid this, a large recessed drain well – sometimes referred to as a 'pump well' or 'bilge well' – was fitted at the after end of each engine and boiler room at the Tank Top level along the center line.

Bilge systems

The ballast and bilge pumps were connected by piping to be available together or separately for either service. The piping was designed so that it was possible to pump water from any flooded compartment by means of two independent bilge suction systems of 10in mains having cross-connections between them.[3] A double line of bilge main pipe was fitted forward of the Boiler Room No.5 and aft of the Boiler Room No.1. By means of these, it was possible to isolate any flooded space, together with any suctions in it. If any of these suctions were accidentally left open and consequently became out of reach, they could be shut off from the main by a hand-wheel above the deck where the corresponding watertight bulkhead terminated.

The bilge suction pipes were led fore-and-aft over the Tank Top, and were located entirely above the Tank Top in the space between the Tank Top and the machinery space deck plates. The suction ends for removing drainage from the bilges were led down into various drain wells and drain pots let into the Tank Top. Drain wells were essentially shallow, open-top tanks which were recessed into the double bottom so that the top was flush with the surrounding inner bottom plating. Drain pots were small cylindrical or oblong receptacles, the appearance of which can be best likened to an inverted top hat. These were riveted to the Tank Top plating beneath holes about the same size and shape as the manholes which provided access into the double bottom. In addition to the various drain pots and drain wells located along the Tank Top, bilge suctions were also led into the natural drainage wells formed by the open bilge wings outside the double bottom within the holds and shaft tunnels.

In the various cargo holds, the fore-and-aft position of the ends of the bilge suctions was determined by certain specifics in the design of the *Olympic*-class ships. Because the ship in most conditions usually had a trim by the stern, the bilge suctions and their associated drain wells and pots were, in most instances, placed at the after end of each compartment. In the forward holds, this arrangement provided a further advantage in that it reduced the length of the piping. Watertight sleeves were employed where the pipes passed through watertight bulkheads. All of the large suction pipes were of the non-return type to ensure the watertight integrity of the accompanying compartments and were provided with valves controlled from the deck above the bulkhead, so that when shut the integrity of the bulkhead was assured.

The end of each suction pipe was surrounded by a strainer, alternately called a 'rose box', 'strum' or 'mud box'. This was a galvanized iron box, 9 to 12in square, having all sides perforated with small holes. Its purpose was to strain the dirty bilge water so that solid matter could not pass into and choke the suction pipe or the valves of the pump. The combined area of perforations was required to be twice that of the sectional area of the internal diameter of the suction pipe so that even when partially choked it could still pass sufficient water. Each strainer had a hinged lid or sliding sides to give access to its interior. The suction pipe was to pass loosely into the box, with its end about 1in above the cement. The box was to be fixed so that it would not move with the rolling of the ship and wear away the cement and pipe. (The suction pipes for pumping out the ballast tanks were not required to have rose boxes as no dirt of the kind likely to cause choking would normally find access to the tanks.) The flooding valves on the vessel's sides (the condenser intakes) through which the tanks were filled were also covered with strainers.

The bilge pumps were arranged to draw water from every compartment in the ship. There were numerous pipes leading to the pumps, but as there was only one pipe in actual connection to each pump, a special union was necessary whereby the pumping power could be distributed as required. This was accomplished by means of a distribution box or 'valve chest'. The valve chest was a rectangular, cast-iron box to which the pump suctions and the various branch suctions connected. In the chest over each branch was a screw-down valve; if all of these were closed, the chest formed a cul-de-sac for the pump suction, and any one that was opened at once formed a continuation of it. Each valve handle was marked with the compartment it controlled and by opening any particular one, the associated hold could be pumped.

Separate valve chests were provided for the forward and after holds, and as the connection to the pumps was made by a single pipe, the total length of piping was minimized by placing the former in the forward stokehold and the latter at the after end of the machinery spaces, where they were always accessible. To save piping, there were multiple chests for each region. Separate pumps were provided for pumping the ballast tanks, for supplying the sanitary mains and the fire and wash-deck mains. All these pumps had a connection (direct or indirect) to the bilge valve chests, so that all the pumping power of the ship (with the exception of the circulating pumps) could be brought to bear on any particular compartment. In order that this concentration of power could be useful, the suction pipes to each hold had to be exceptionally large.

Special pumping power was provided for the machinery spaces, because not only was water particularly liable to accumulate there, but the suction pipes were apt to become choked by the coal dust, ashes, grease, bits of waste, etc., which always gathered in the machinery bilges. *Titanic*'s three steam-powered bilge pumps were manufactured by Harland & Wolff, each having a capacity of 150 tons per hour. They were of vertical duplex design with steam cylinders of 10in diameter, pump barrels of 10in diameter and a stroke of 12in.

One vertical duplex Harland & Wolff ash ejector pump was placed in each of the large boiler compartments[4] to work the ash ejectors and to circulate or feed the boilers as required. These pumps were also connected to the bilges, except in three of the boiler rooms where three of the ballast and bilge pumps were placed. The pumps in each case had direct bilge suctions as well as a connection to the main bilge pipes, so that each boiler room would be independent. The following suctions were provided to the various engine and boiler rooms:

Sizes and Locations of Main Bilge Suctions

No.6 Boiler Room:	three 3½in, one 4½in and two 3in suctions
No.5 Boiler Room:	three 3½in, one 5in and two 3in suctions
No.4 Boiler Room:	three 3½in, one 4½in and two 3in suctions
No.3 Boiler Room:	three 3½in, one 5in and two 3in suctions
No.2 Boiler Room:	three 3½in, one 5in and two 3in suctions
No.1 Boiler Room:	two 3½in, one 5in and two 3in suctions
Reciprocating Engine Room:	two 3½in, six 3in, two 18in and two 5in suctions
Turbine Engine Room:	two 3½in, three 3in, two 18in, two 5in and one 4in suctions
Electric Engine Room:	four 3½in suctions

In addition, in the store rooms above the Electric Engine Room there was an extra suction pipe provided that required manual handling to be carried to the intended pump.

In an emergency, large volumes of water could be removed from the engine room bilges by utilizing the four gunmetal condenser-circulating pumps. These pumps are described in detail in the chapter devoted to the propelling machinery. Besides their main sea suctions, each pump was provided with an 18in direct bilge suction. The two after pumps had bilge suctions from the Turbine Engine Room while the two forward pumps had bilge suctions from the Reciprocating Engine Room. The circulating pumps were the most powerful pumps on the ship due to the large volume of water that was required to thoroughly cool the condenser tubes. When made to draw their supply of water from the bilge instead of from the sea, they were capable of clearing away a considerable amount of bilge water while still cooling the condensers. The bilge suctions, or 'bilge injections' as they were called (referring to the 'injection' into the condenser of bilge water instead of sea water), were led down to the Tank Top where they were readily accessible for examination and clearing.

Throughout the boiler and engine rooms, *Titanic*'s Tank Top sloped upward above the bilges, causing any drainage water that collected upon it to flow naturally towards the centerline. To collect the bilge water flowing from

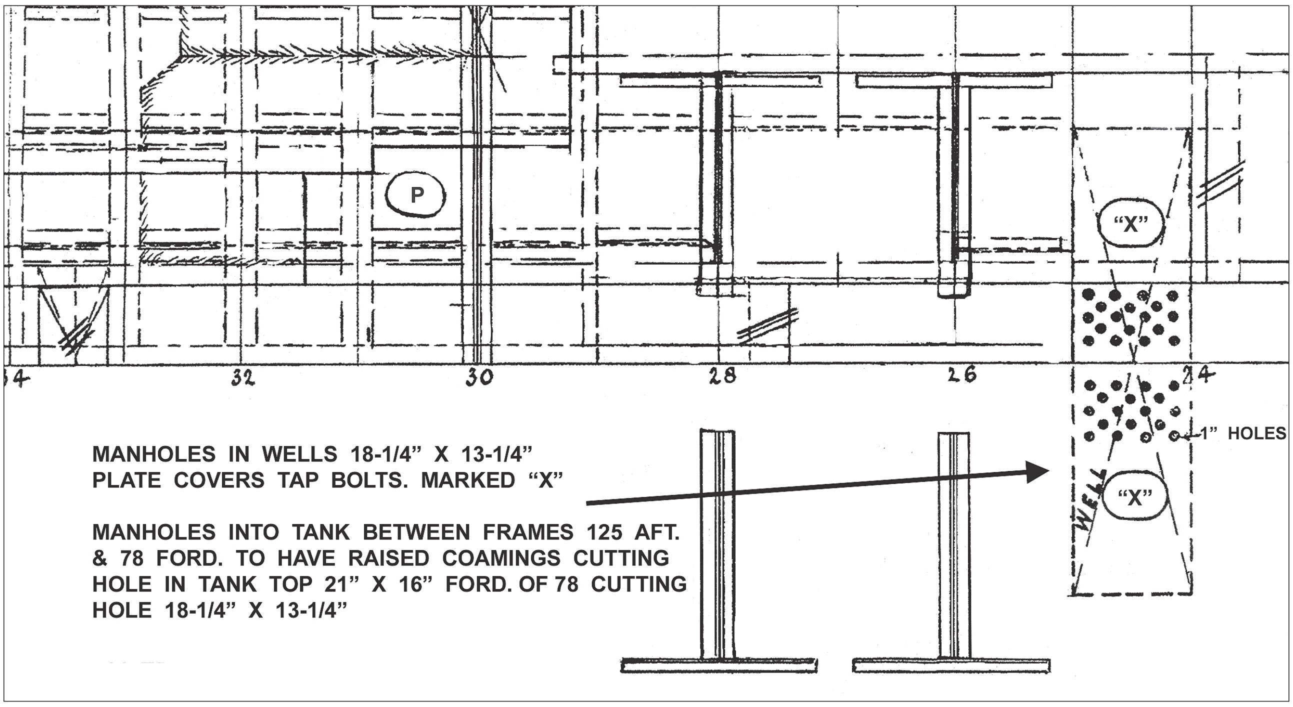

P
"X"
34
32
30
28
26
24
1" HOLES
WELL
"X"
MANHOLES IN WELLS 18-1/4" X 13-1/4"
PLATE COVERS TAP BOLTS. MARKED "X"
MANHOLES INTO TANK BETWEEN FRAMES 125 AFT.
& 78 FORD. TO HAVE RAISED COAMINGS CUTTING
HOLE IN TANK TOP 21" X 16" FORD. OF 78 CUTTING
HOLE 18-1/4" X 13-1/4"

Fig. 16-5 **Illustration of Drain Well** – Illustration showing a portion of 400-401's Tank Top plating. This illustration indicates the specifications for the manholes (letter 'P' indicating the presence of a removable watertight cover plate) and the centerline drain well in Boiler Room No.1 is also shown. The T-shaped objects are the double angle bar footings for boiler seats. *(Illustration by Bruce Beveridge based on original H&W Tank Top plan)*

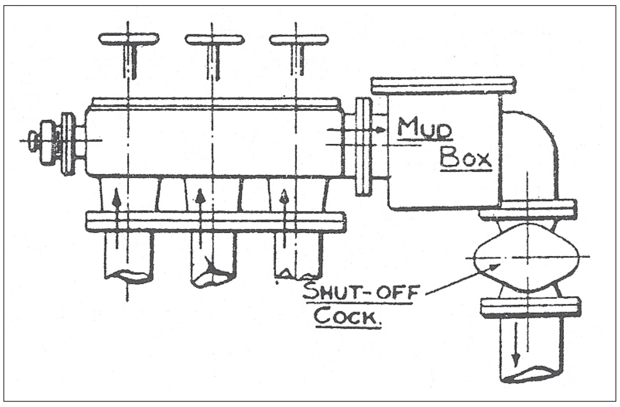

MUD
BOX
SHUT-OFF
COCK.

Fig. 16-6 **Bilge Suction Chest** – Typical bilge suction chest as found throughout the engine and boiler spaces, and in the shaft tunnels, with a mud box fitted at the inlet.

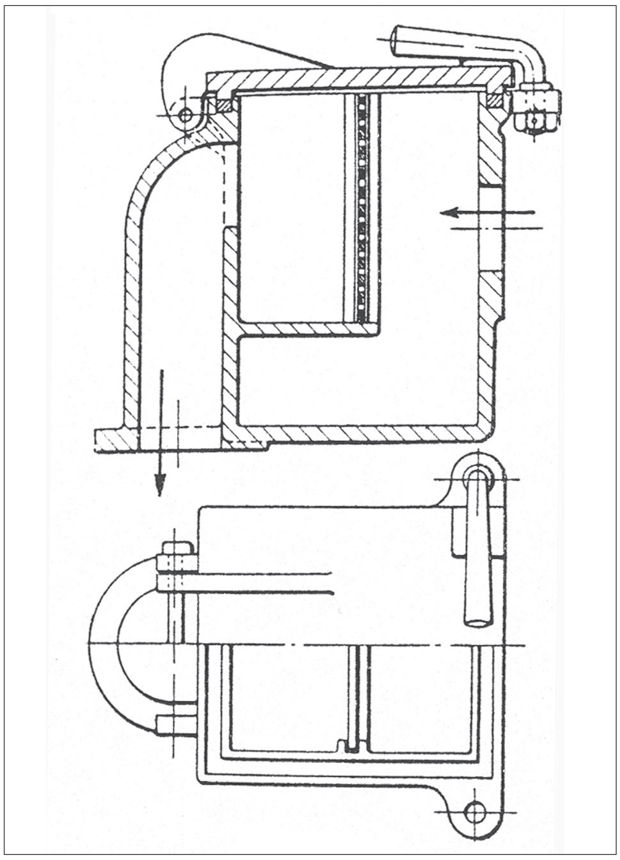


Fig. 16-7 **Details of Bilge Suction Mud Box** – The lid handle is shown in correct position in the plan view, but is shown projecting to the right in the sectional elevation in order illustrate all of the features.

the sides of the hull in these compartments, a number of the various bilge suctions were led down into large drain wells located along the centerline of the ship, while others were led into drain pots located some distance off to either side. All but one of these drain wells was were located symmetrically about the centerline of the hull, the only exception being the one in Boiler Room No.2, which was located immediately to port of center. They

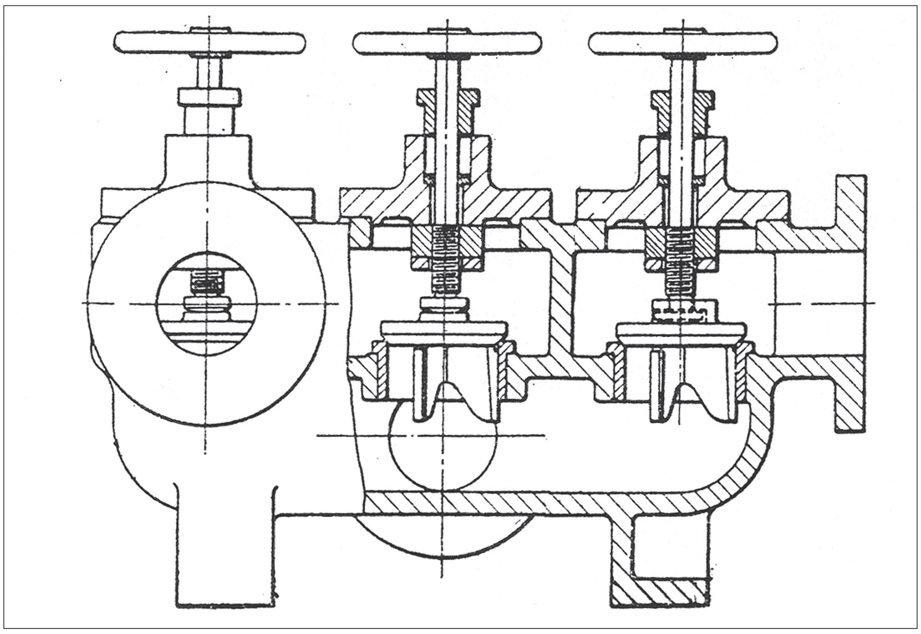
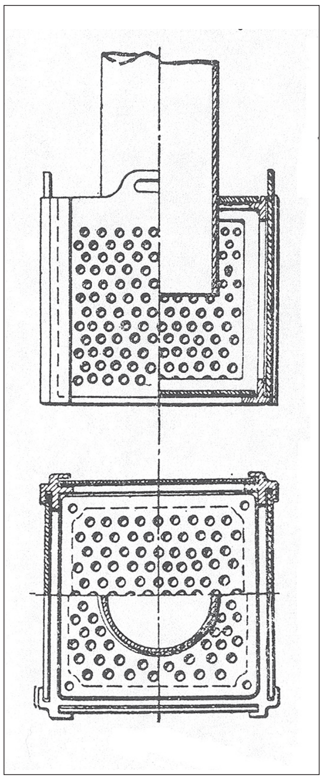
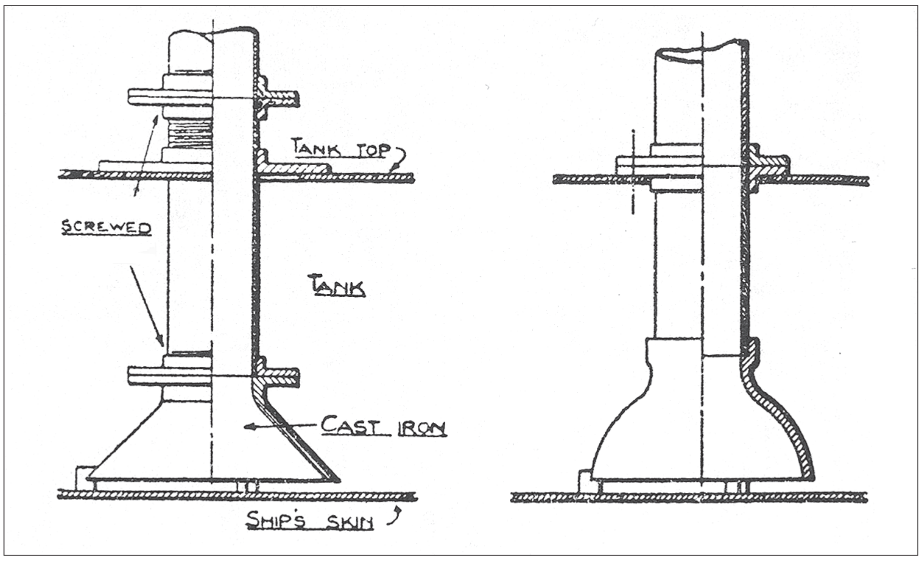


Fig. 16-8 **Multiple-Chest Valve** – Internal components typical to multiple-chest valves, used in the bilge pumping and ballast transfer system. Valves of this type were connected to each of the pumps in the five forward boiler rooms, and also to any of the pumps within the engine rooms that were provided with connections to the bilge and ballast piping.



Above Fig. 16-10 **Typical Strainer Box** – Typical strainer box enclosing the free end of a suction pipe. Strainers of this type were fitted in the bilges beneath the boiler and machinery spaces to exclude coal fragments, ash and other debris large enough to choke to the pump suctions.


TANK TOP
SCREWED
TANK
CAST IRON
SHIP'S SKIN

Left Fig. 16-9 **Two Forms of Suction Ends –** Two forms of suction ends used for ballast and fresh water suctions.

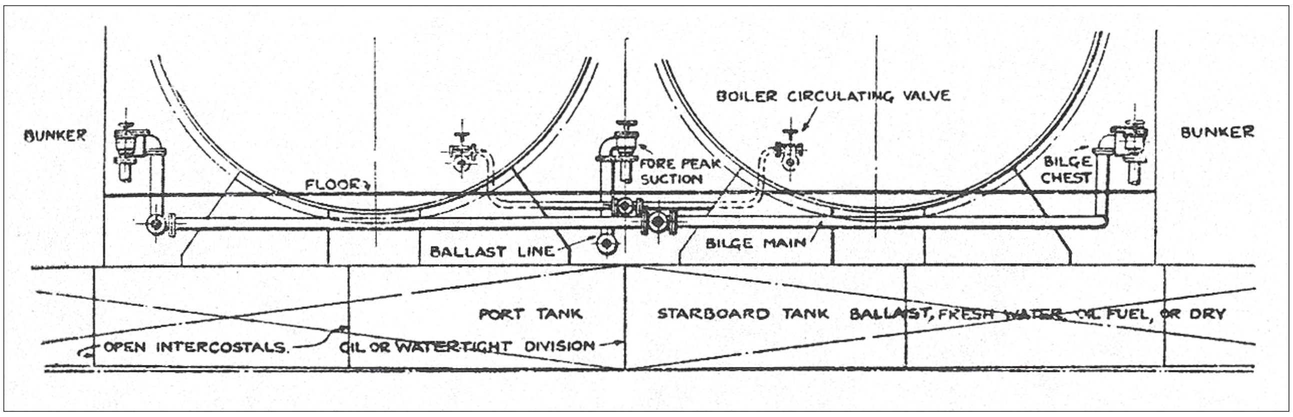

BUNKER
BOILER CIRCULATING VALVE
BUNKER
FORE PEAK SUCTION
BILGE CHEST
FLOOR
BALLAST LINE
BILGE MAIN
PORT TANK
STARBOARD TANK
BALLAST, FRESH WATER, OIL FUEL, OR DRY
OPEN INTERCOSTALS.
OIL OR WATERTIGHT DIVISION

Fig. 16-11 **Sectional Elevation Showing Under-Floor Piping** – This sectional elevation shows the under-floor piping and connections commonly found in way of the boiler rooms in connection with the bilge and ballast pumps. In addition to ballast and bilge pumping, Harland & Wolff arranged connections to allow these pumps to be used as auxiliary feed pumps. They were also used for circulating the water within the boilers both during warm-up and while operating any boiler with the fires banked.

satisfactorily.

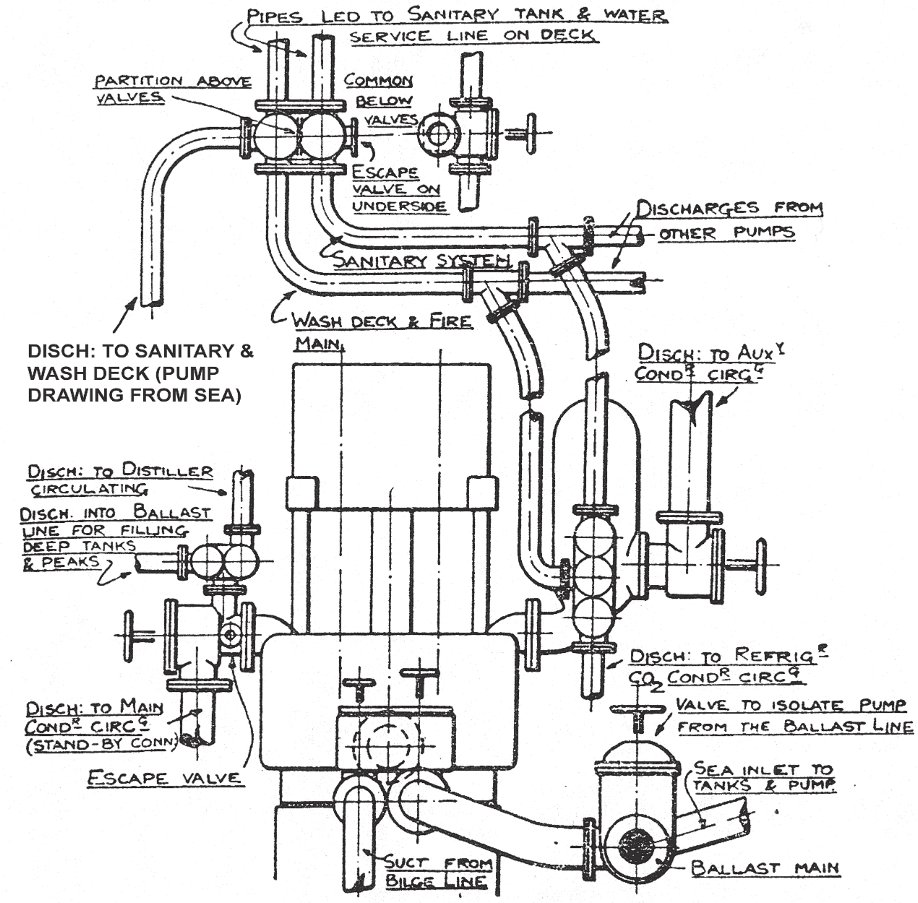

PIPES LED TO SANITARY TANK & WATER SERVICE LINE ON DECK
PARTITION ABOVE VALVES
COMMON BELOW VALVES
ESCAPE VALVE ON UNDERSIDE
DISCHARGES FROM OTHER PUMPS
SANITARY SYSTEM
WASH DECK & FIRE MAIN
DISCH: TO SANITARY & WASH DECK (PUMP DRAWING FROM SEA)
DISCH: TO AUX^Y COND^R CIRC^G
DISCH: TO DISTILLER CIRCULATING
DISCH. INTO BALLAST LINE FOR FILLING DEEP TANKS & PEAKS
DISCH: TO REFRIG^R CO2 COND^R CIRC^G
VALVE TO ISOLATE PUMP FROM THE BALLAST LINE
DISCH: TO MAIN COND^R CIRC^G (STAND-BY CONN)
SEA INLET TO TANKS & PUMP
ESCAPE VALVE
SUCT FROM BILGE LINE
BALLAST MAIN

Fig. 16-12 **Ballast Pump Discharge Connections** – While this figure illustrates the typical discharge connections that may be provided at any ballast pump, not every ballast pump on a ship will have all of the connections indicated.

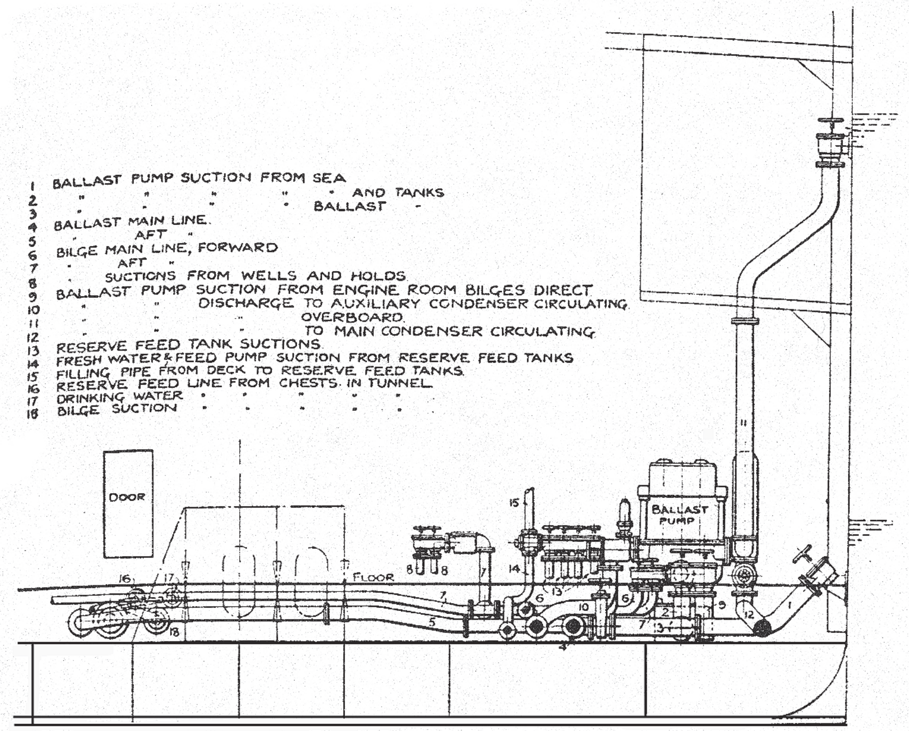

1 BALLAST PUMP SUCTION FROM SEA
2 " " " " " AND TANKS
3 " " " " BALLAST "
4 BALLAST MAIN LINE.
5 " AFT "
6 BILGE MAIN LINE, FORWARD
7 " AFT "
8 " SUCTIONS FROM WELLS AND HOLDS
9 BALLAST PUMP SUCTION FROM ENGINE ROOM BILGES DIRECT
10 " " DISCHARGE TO AUXILIARY CONDENSER CIRCULATING.
11 " " " OVERBOARD.
12 " " " TO MAIN CONDENSER CIRCULATING.
13 RESERVE FEED TANK SUCTIONS.
14 FRESH WATER & FEED PUMP SUCTION FROM RESERVE FEED TANKS
15 FILLING PIPE FROM DECK TO RESERVE FEED TANKS.
16 RESERVE FEED LINE FROM CHESTS IN TUNNEL.
17 DRINKING WATER " " " " "
18 BILGE SUCTION " " " " "
DOOR
FLOOR
BALLAST PUMP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Fig. 92.

Fig. 16-13 **Under-Floor Piping and Connections** – This sectional elevation shows the common under-floor piping and connections associated with the bilge and ballast pumps. The specifics of each arrangement varied with the vessel's size and the number of pumps employed.

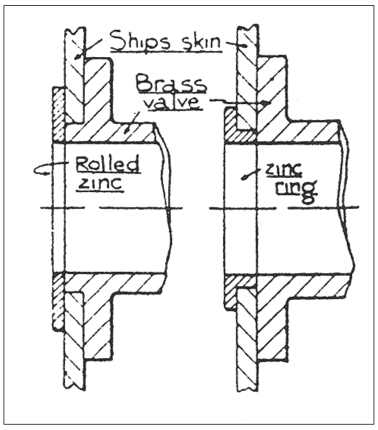


Fig. 16-14 **Typical Brass Through-Hull Fittings** – Typical brass through-hull fittings, showing zinc rings fitted to prevent damage through galvanic action. Larger openings had zinc slabs or strips secured to the plating around the opening.

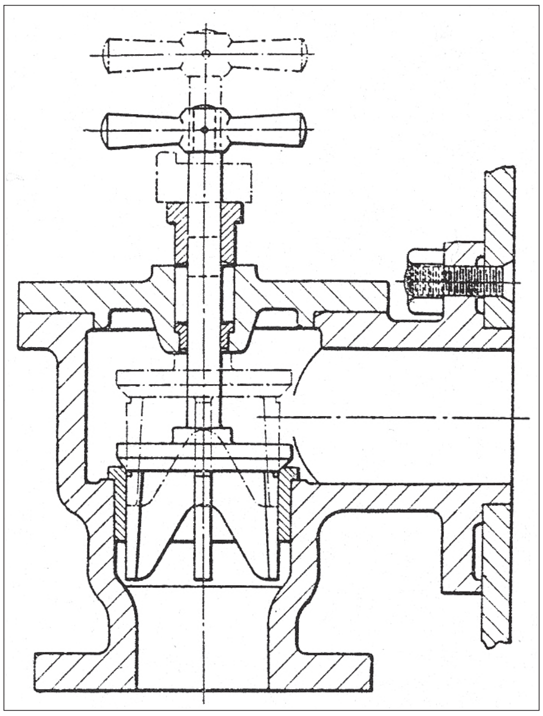


Fig. 16-15 **Discharge Valve of the Non-Return Lift Type** – Typical small discharge valve of the non-return lift type. Such valves were required on all discharge openings from the bilge, ballast and other pumping systems to prevent flooding in the event that any part of the system should fail.

each measured 3ft x 12ft, with the exception of the one in Boiler Room No.6 which measured 3ft x 10ft 6in. To preserve the integrity of the plating, each drain well was formed as a box-like structure attached to the underside of a section of Tank Top plating which was pierced above the well with a series of 1in drain holes. Two manholes were provided into each well to allow access for cleaning and maintenance. In addition to the centerline drain well and the drain pots located within the main space of each boiler room, a drain pot and branch suction was located at the after end of each passageway leading between the boiler rooms; this was provided to collect and remove any bilge water that might find its way aft past the perforations above the drainage wells.

At the after end of both shaft tunnels, two 3½in suctions were provided to remove the collected drainage from the water used to cool the shaft bearings and leakage water from the stern tube glands. In the forward shaft tunnel, the suctions were led into drainage wells on the port and starboard sides formed by the open bilge wings outside the margin of the double bottom. In the after shaft tunnel, a drainage well was formed by the open bilges between the watertight floor forming the after end of the double bottom at frame 125A, and WTB P at frame 133A, and divided by the vertical keel plate. The fitting of separate long suction pipes to the pump valve chests was avoided by leading branch suctions from each well to a small valve chest, and then connecting this chest by a single pipe to the pump valve chests forward. In order to avoid the possibility of either tunnel becoming flooded with water when the valves to all suctions happened to be open, the valves were of the non-return type and were fitted with control rods

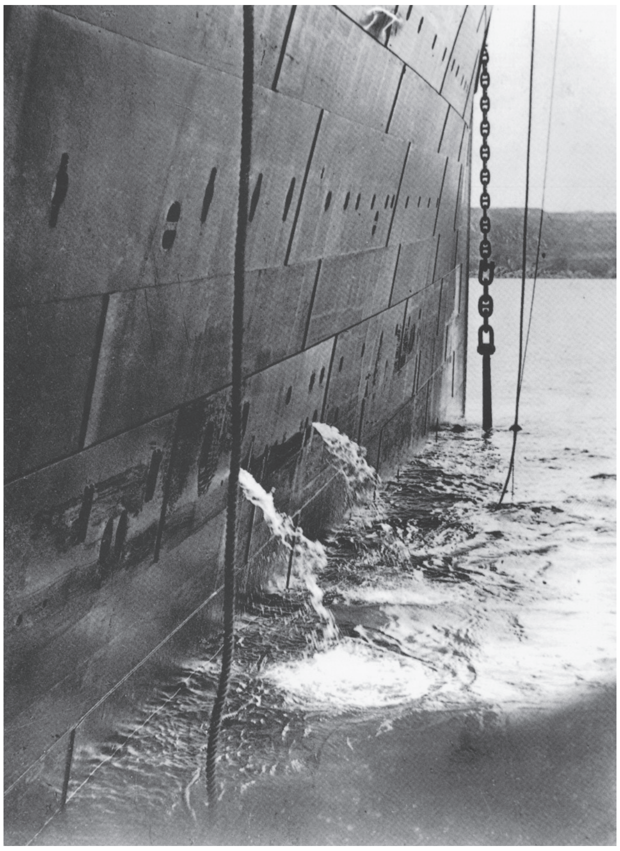


Fig. 16-16 **Sanitary Water Discharge** – Among the details captured in this image is the discharging of sanitary water from soil pipes along *Titanic*'s starboard bow. The term 'sanitary' water is something of a misnomer here, as this discharge was anything but sanitary! *(Father Browne photograph/Authors' collection)*

to the bulkhead deck above. Because the After Peak Tank was a ballast tank, its suction pipe was also fitted as a branch to the aforementioned valve chest. In addition to the suctions provided in the shaft tunnels below, the watertight flats above shaft tunnel were each provided with two 3in suctions.

In the Nos 1, 2 and 3 Holds two 3½in bilge suctions were lead directly into the bilge wings of each hold; furthermore, an additional pair of 3in suctions was provided in each of the latter two holds. Provisions were also made for removal of bilge water in the Firemen's Tunnel, the watertight pipe tunnel extending from Boiler Room No.6 to the after end of the No.1 Hold. The valves in connection with the forward bilge and ballast suctions were placed within the Tunnel, and the Tunnel itself was provided with several suctions. In addition to two 3in bilge suctions, one at each end, there was a special 3½in suction with valve rod led up to the Lower Deck (G) where it would remain accessible if the Firemen's Tunnel became flooded. In the vestibule between the Firemen's Tunnel and Boiler Room No.6 there were two 3½in suctions.

Salt Water System

Sanitary water

Passenger ships required the use of thousands of gallons of water daily to meet the demand for deck washing, fire fighting, bathing and flushing water closets. For these purposes, salt water (sea water) was used. One feature consistent to the sanitary water systems aboard ocean liners of the time, including *Olympic*, is that sea water was pumped up to large storage tanks, or 'cisterns', on the highest decks of these ships. From these 'sanitary tanks' the water then flowed back down to the supply piping and thence to the accommodations by gravitational force. As the pumps were always at work, there was a constant overflow from the sanitary tanks, which, instead of being passed overboard directly, was conveyed into the soil pipes to continuously flush them.[5]

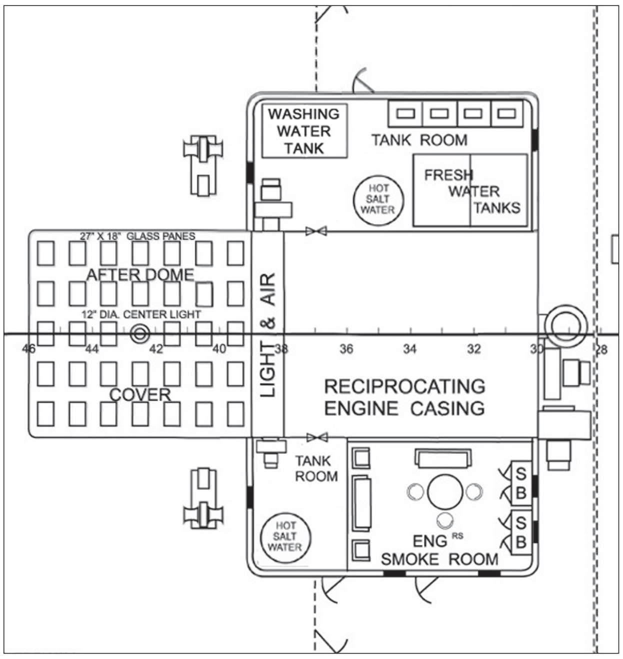


Fig. 16-17 **Water Tanks Plan** – Plan of the water tanks in *Titanic*'s Tank Rooms; these rooms shared a deckhouse with the Engineers' Smoke Room. *(Illustration by Bruce Beveridge)*

This system worked well enough on ships of moderate size, and was originally employed on *Olympic*. However, as ships grew larger and the demands on the sanitary water system increased, the number and size of the supply tanks increased in response. In addition to the increased pumping capacity and resulting increase in steam consumption, the most serious consequence of fitting so many large water storage tanks to the upper decks of a ship was the negative impact they had on the ship's stability. Experience with *Olympic* in this area resulted in a change for *Titanic* which was something of a departure from the usual shipboard systems of the era.

On *Titanic*, a hydrostatically operated pumping system was employed. In lieu of the ordinary system of sanitary tanks, a looped standpipe of fairly large diameter was led some distance up the No.3 Funnel.[6] As soon as the water being delivered by the sanitary pumps ascended the pipe to a level near the top of the loop, the head of water within the standpipe became sufficient to cause a controller to shut down the steam supply at the pumps. Any potential overflow within the standpipe flowed across the top of the loop to the opposite side where it drained by gravity to the bilges below. The moment the water column in the standpipe started to fall in response to usage within the system and the drop in pressure was sensed, the controller restarted the pumps and additional water was delivered to fulfill the demand. The controller and manner in which it operated the steam supply to the pumps will be dealt with shortly.

It must be remembered that *Titanic* was built during a period of transition. The White Star Line utilized *Olympic*'s first season of service as a test bed and upgraded both *Titanic* and *Britannic* based on experience obtained with the first ship of the class. A detailed general arrangement plan of *Titanic* apparently still exists, small portions of which can be viewed in a scant few seconds of television documentary video footage. Though only the after end of the Boat Deck is shown, enough of the plan is in view to reveal her water tanks abaft the No.3 Funnel. It is from this plan that we can confirm the absence of the sanitary tanks.

The specification book for *Olympic* as completed in 1911 shows that she was fitted with sanitary tanks on her Boat Deck, port and starboard, of 2,300 gallons each. The supply of sanitary water on the newer *Britannic* was regulated from the Reciprocating Engine Room by means of a control valve, which rendered unnecessary a large reservoir on the Boat Deck. A General Arrangement plan of *Olympic* from the 1930s indicates the absence of sanitary tanks on her Boat Deck. Since it is known from Harland & Wolff's Drawing Office Notebook that these tanks were originally specified, the lack of sanitary tanks shown on the later general arrangement plan indicates they were removed some time after 1911 during one of her refits. Furthermore, *Olympic* did not enter service in 1911 with an Engineers Smoke Room on the Boat Deck abeam the reciprocating engine casing. This 'omission' made available the entire starboard-side Tank Room for a large sanitary tank. In 1913, when *Olympic* re-entered service upon completion of her refit following *Titanic*'s sinking, the Engineers' Smoke Room had been added to this location. *Titanic*, however, was built with this accommodation from the start. This suggests that the Engineers' Smoke Room was added to *Olympic* in the space reclaimed by the removal of the sanitary tank in the starboard-side Tank Room.

Sea water was pumped directly from the ocean to distribution circuits via the sanitary pumps. *Titanic* had four sanitary water pumps of the vertical duplex type, supplied by Harland & Wolff, each with a capacity of 250 tons per hour at moderate speed. They had 12in steam and pump cylinders with a 15in stroke. To substitute for the force of gravity that would have been afforded by a sanitary tank on the Boat Deck, the sanitary pumps maintained a pressure of about 55psi in the supply pipe at all times. This ensured a minimum pressure at the Boat Deck level of at least 5psi. A hydrostatic control valve of the piston type was fitted in line with the steam supply pipe near the pumps. A small pipe was fitted between the control piston of the valve and the very bottom end of the standpipe so that the rise and fall of pressure in the standpipe raised or lowered the piston of the valve, thereby cutting off or admitting steam to the sanitary pumps. The steam valve in this controller was held open by a spring, opposed by a column of water equal in height to the water standing in the sanitary

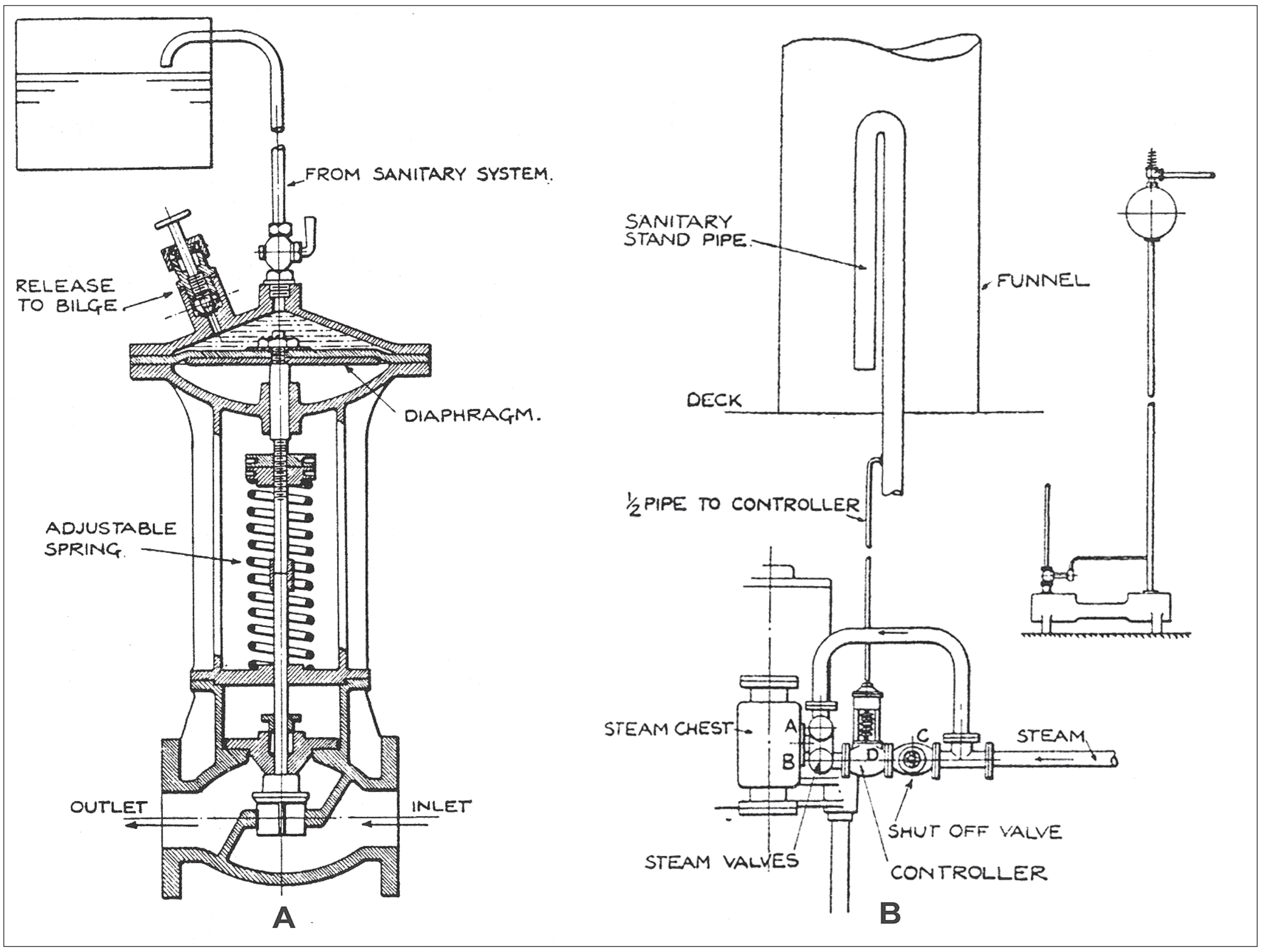


Fig. 16-18 **Hydrostatic Control** – 'A' shows a sectional view of a hydrostatically controlled steam supply valve; 'B' shows a diagrammatic representation of the hydrostatic control system for the steam supply to the sanitary and fresh water pumps *(Both illustrations authors' collection)*

system, weighing down upon a piston whose underside was free of pressure. As long as the sanitary system was only partially filled with water, the steam valve was held open by the spring, thereby permitting the pump to work. By the time the sanitary standpipe had filled enough to overflow, the pressure of the water on the piston overcame the resisting power of the spring and the valve was closed. This stopped the pump until the water level fell in the system and the spring once more was able to assert itself against the static head of the water column. The opening through the steam valve was, therefore, proportionate to the height of the water column. The domestic fresh water system was controlled in exactly the same manner as the sanitary (salt water) system, except that there was a deck tank for the reception of the fresh water.

Water was distributed to the supply piping fore-and-aft through galvanized iron mains, which were led along under the deck beams and which had branches with shut-off valves to the various appliances. The water pipes feeding the water closets, bathrooms and lavatories were galvanized iron with lead-in pipes made of lead. As with modern plumbing, the water pipes that supplied the sanitary appliances were provided with local shut-off valves to the individual appliances.

The pipes carrying the sanitary water used to flush the soil pipes were fitted with clearing plugs so that a rod could be inserted to clear away any obstructions. These plugs were required at any sharp bend or turn in a pipe that passed solid matter.

Hot salt water for bathing was distributed in much the same way as stated above but utilized elevated tanks at the Boat Deck level. These tanks of hot salt water were housed within the Tank Rooms to provide for the accommodations below the Boat Deck level. Two additional 310-gallon hot salt water tanks within the No.1 Funnel casing supplied the officers' quarters and

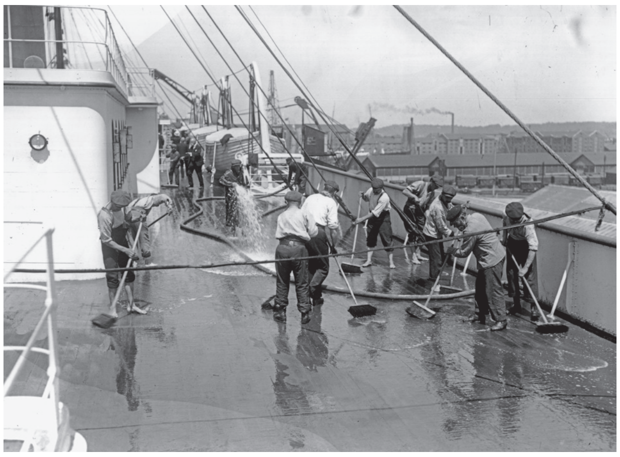


Fig. 16-19 **Washing the Deck on *Olympic*** – Crewmen washing the deck aboard *Olympic* in 1911. The water main that serviced the Boat Deck was designated the 'Wash Deck' supply on *Olympic*'s plans, although these bibbs and hoses were intended be used for firefighting as well.

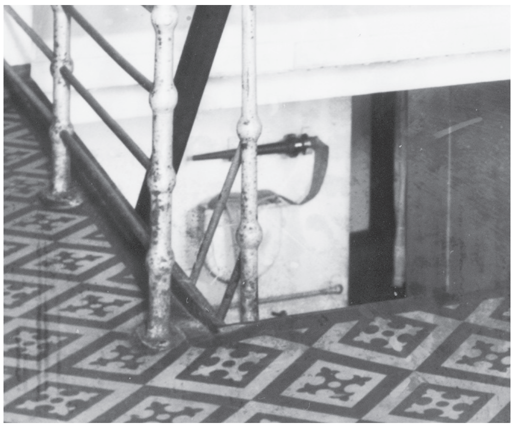


Fig. 16-20 **Firehose** – A firehose stowed in *Olympic*'s Third Class main companionway on D Deck; the hose nozzle is visible here. *(Daniel Klistorner collection)*

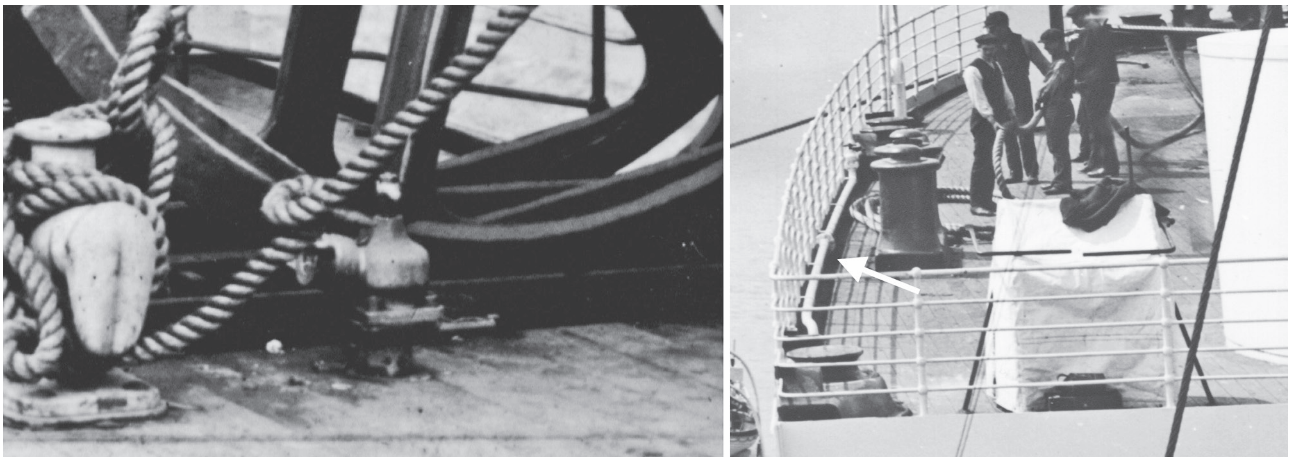


Fig. 16-21 **Hose Bibb on Boat Deck** – At left, one of *Olympic*'s Boat Deck hose bibbs. The image at right shows a length of wash deck main running along the waterway of *Olympic*'s Poop Deck, with the white arrow indicating the pipe. *(Both images from authors' collection)*

the forward First Class staterooms. These same tanks also supplied hot salt water to the Swimming Bath on F Deck. A vertical duplex steam pump was located in the turbine engine room to send the hot salt water from the discharge pipes of the main condensers to these cisterns at the top of the ship. A float valve controlled the water supply, and electrically controlled valves maintained the temperature at a predetermined level.

Fire mains

In all vessels, provision for extinguishing fires was of paramount concern. Though on *Titanic* there were provisions for steam extinguishing in the boiler rooms, machinery spaces and cargo compartments, water was used for the decks, passageways and accommodations. Some ships utilized the sanitary pumps to supply the fire mains, but large passenger steamers had independent steam pumps for this purpose.

Titanic's certification papers indicate that she was fitted with three fire pumps, which discharged into the fire mains. The fire mains were a series of large-diameter, galvanized iron pipes led fore-and-aft along the sides of decks, promenades and passageways. Connected to these mains at intervals of about 50ft were deck hydrants with bibcocks, or 'bibbs', as they were occasionally referred to. Their placement at regular intervals ensured that fire hoses could reach every part of the ship. These were also used on the weather decks as a supply of water for washing the decks.

The hoses were stored on reels and made of 2½in-diameter canvas for use in passageways, interior spaces, and deck areas. 1½in-diameter hose was also provided for deck washing.[7] The hose couplings were of 'Nunan's' type. The length of hose sections was generally 50ft.[8] Branches led from the vertical mains, or 'risers', to serve the various 'tween-deck spaces and across the decks where the central part was blocked by deckhouses or casings. When a fire drill was held aboard *Titanic* (usually on Sundays) assigned deck personnel would lay out the lengths of fire hose at predetermined locations near the deck hydrants.

Although regulations covering fire equipment were vague in 1912 and would not become stringent until after the First World War, they did specify that chemical fire extinguishers were required in the steerage compartments. However, records from *Olympic* as well as *Britannic* show that fire extinguishers were also placed in areas such as the First Class corridors and entrance halls, and bore the brand name 'Fire Queen'.

In photographs of *Titanic* in 1911 and *Olympic* in 1911 and 1912, there is no evidence of fire hoses being stowed in the open on the weather decks. Noticeably visible open hose reels or canvas hose containers with an adjacent nozzle do not appear in photographs of *Olympic* until the First World War. This does not mean they were missing from *Titanic*'s weather decks, only that they were stowed elsewhere.

Furthermore, open lights were not to be carried about the ship into the staterooms or holds. Matches were not allowed to be taken on board by any member of the crew, as the company supplied safety matches for the use of everyone on board.[9]

FRESH WATER SYSTEM

Fresh water storage tanks were located throughout the lower structure of the hull. Their containing walls were

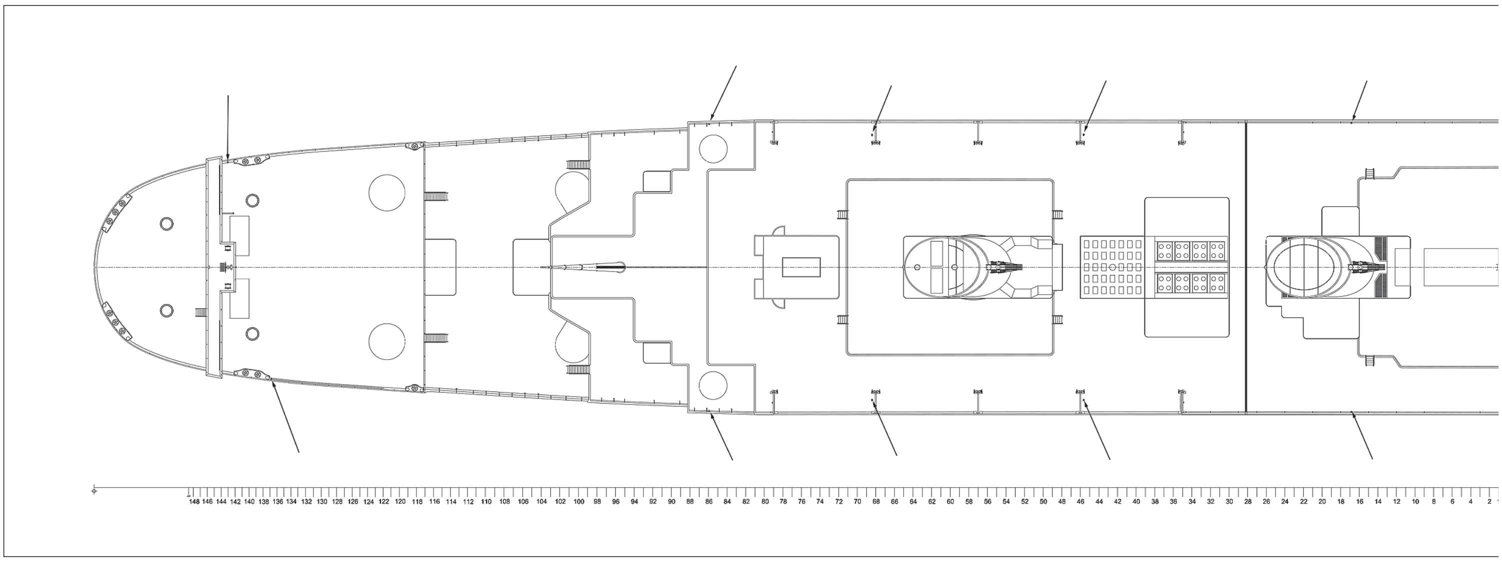


Fig. 16-22 **Illustration of Weather Deck Bibbs** – An illustration showing the location of all of the water bibbs seen on the open weather decks. *(Illustration by Bob Read)*

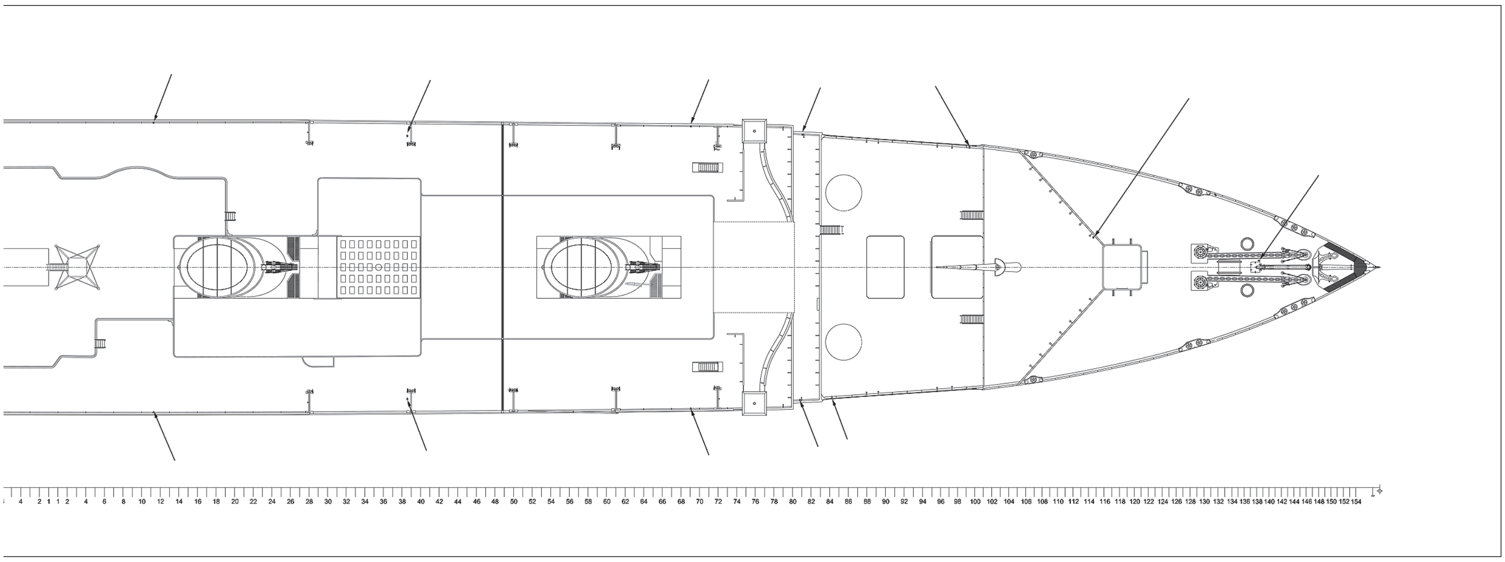
formed by the vessel's bulkheads, decks, and side plating. Fresh water intended for boiler feed-water or for washing water was stored in tanks in the double bottom. The storage tanks for drinking water were located above the double bottom and were designated solely for that purpose. These tanks were emptied and refilled at the end of each voyage.

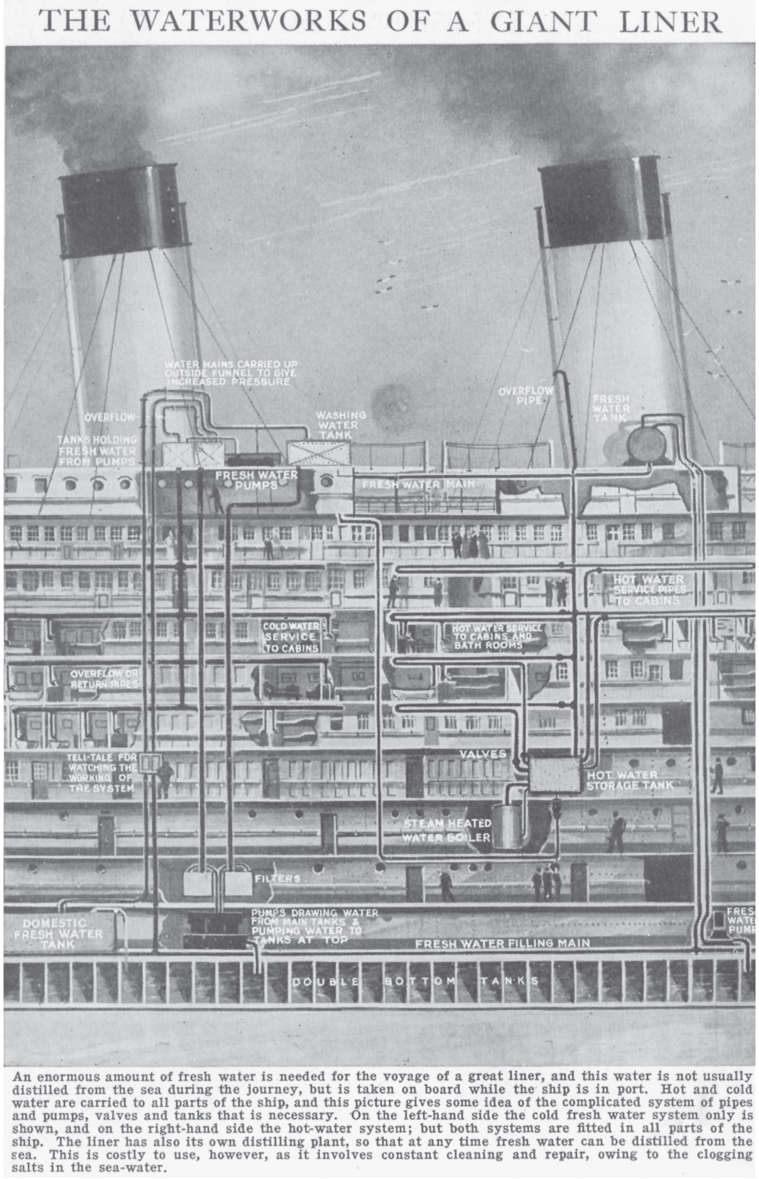
Individual tanks were advantageous in that there was no chance of the entire supply being spoiled by salt water leakage into a single tank. Six of the seven tanks for drinking water on *Titanic* were positioned along the sides of the hull between Watertight Bulkheads M and N; these tanks (three to port and three to starboard of the electrical machinery) held a combined total of 792 tons. A smaller tank with a capacity of 170 tons was fitted forward between frames 93F and 95F. This tank spanned the breadth of the ship up to the Orlop Deck in the form of a cofferdam. Cumulatively all seven tanks held 962 tons of drinking water, or 258,216 gallons. Each tank was provided with an air and sounding pipe, a manhole and a drain plug; within each tank there was also a suction pipe to the steam pumps in the Reciprocating Engine Room. The tanks were to be cleaned out periodically and painted with a cement wash.

Evaporators were used to supply boiler feed make-up as well supplement or replace the supply of fresh water carried for domestic purposes in the event the supply became contaminated or was found to be insufficient in quantity. The production of fresh water from salt water was accomplished by the vaporization of sea water and then cooling (condensing) the steam produced. When supplied as feed make-up, this was accomplished by introducing the steam into the main condensers, or by introducing it into the surface feed heater through the auxiliary exhaust steam line. When producing fresh water for drinking purposes, the steam from the evaporators was condensed by passing it through distillers which contained coils chilled by a constant flow of cold sea water. The fresh water produced by the evaporators was without aeration and trace minerals, making it ideal for boiler feed purposes; unfortunately, due to these very same characteristics it had a flat taste and could be quite unpalatable. To make this water suitable for drinking purposes, the distillers functioned not only to condense steam from the evaporators into water for the drinking supply, but also to aerate the water and remove any remaining chemical impurities before discharging it to the fresh water tanks. Because a large amount of steam was needed for distilling salt water into drinking water at sea, ships usually obtained their water for both boiler feed and domestic uses from dockside while in port, usually brought by water tender. The evaporators and distillers for this purpose were intended for emergencies only.[10] The particulars of the evaporators and distillers are covered in Chapter 15 of this volume.

Drinking water

Water intended for drinking (including use for food preparation in the galleys) was drawn from the storage tanks abeam of the Electric Engine Room and pumped through a Railton & Campbell filter in the Reciprocating Engine Room, from which it passed to a tank on the Boat Deck. From this storage tank the water proceeded through a Pasteur filter into another tank. It then commenced to flow down by gravitational





THE WATERWORKS OF A GIANT LINER

WATER MAINS CARRIED UP OUTSIDE FUNNEL TO GIVE INCREASED PRESSURE
OVERFLOW
TANKS HOLDING FRESH WATER FROM PUMPS
WASHING WATER TANK
OVERFLOW PIPE
FRESH WATER TANK
FRESH WATER PUMPS
FRESH WATER MAIN
HOT WATER SERVICE PIPES TO CABINS
COLD WATER SERVICE TO CABINS
HOT WATER SERVICE TO CABINS AND BATH ROOMS
OVERFLOW OR RETURN PIPES
TELL-TALE FOR WATCHING THE WORKING OF THE SYSTEM
VALVES
HOT WATER STORAGE TANK
STEAM HEATED WATER BOILER
FILTERS
DOMESTIC FRESH WATER TANK
PUMPS DRAWING WATER FROM MAIN TANKS & PUMPING WATER TO TANKS AT TOP
FRESH WATER FILLING MAIN
DOUBLE BOTTOM TANKS

An enormous amount of fresh water is needed for the voyage of a great liner, and this water is not usually distilled from the sea during the journey, but is taken on board while the ship is in port. Hot and cold water are carried to all parts of the ship, and this picture gives some idea of the complicated system of pipes and pumps, valves and tanks that is necessary. On the left-hand side the cold fresh water system only is shown, and on the right-hand side the hot-water system; but both systems are fitted in all parts of the ship. The liner has also its own distilling plant, so that at any time fresh water can be distilled from the sea. This is costly to use, however, as it involves constant cleaning and repair, owing to the clogging salts in the sea-water.

Fig. 16-23 **The Waterworks of a Giant Liner** – An illustration from an early 1920s book called *The Book of Familiar Things*. This image shows the domestic fresh water systems of a ship approximately the size of one of the White Star Line's 'Big Four' liners. Though a bit smaller in scope, the basic system depicted here was used on the *Olympic*-class liners. *(William Daystrom collection)*

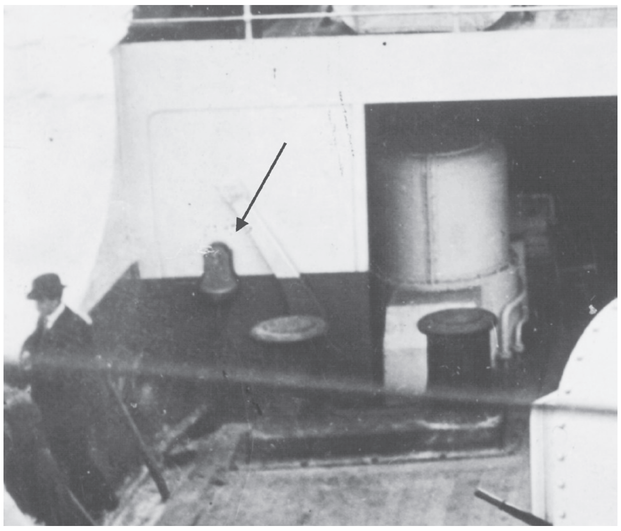


Fig. 16-24 **Cupless Drinking Fountain** – A cupless drinking fountain for Third Class passengers, located in *Titanic*'s after Well Deck. A similar fountain would be installed on *Olympic* before her 1912-13 refit. The object mounted to the bulkhead just to the right of the bell-shaped drinking fountain is a propeller spanner wrench.

force to the supply piping. Cooled drinking water was also supplied in some areas of the ship, such as the main pantries, that were serviced by the refrigerating plant.

Bronze water fountains were positioned around the ship for use of passengers and crew alike. Termed 'cupless' drinking fountains, they resembled a modern-day water fountain. They could be found in the after Well Deck against the after bulkhead under the edge of the Poop Deck, on D Deck in the Third Class open space, at the head of the spiral crew staircases and other places such as main passageways and companionways.

Washing water

A large tank for washing water was placed on the Boat Deck in the Tank Room on the port side of the reciprocating engine casing. A smaller tank fitted on top of the forward boiler casing supplied the Officers' Quarters

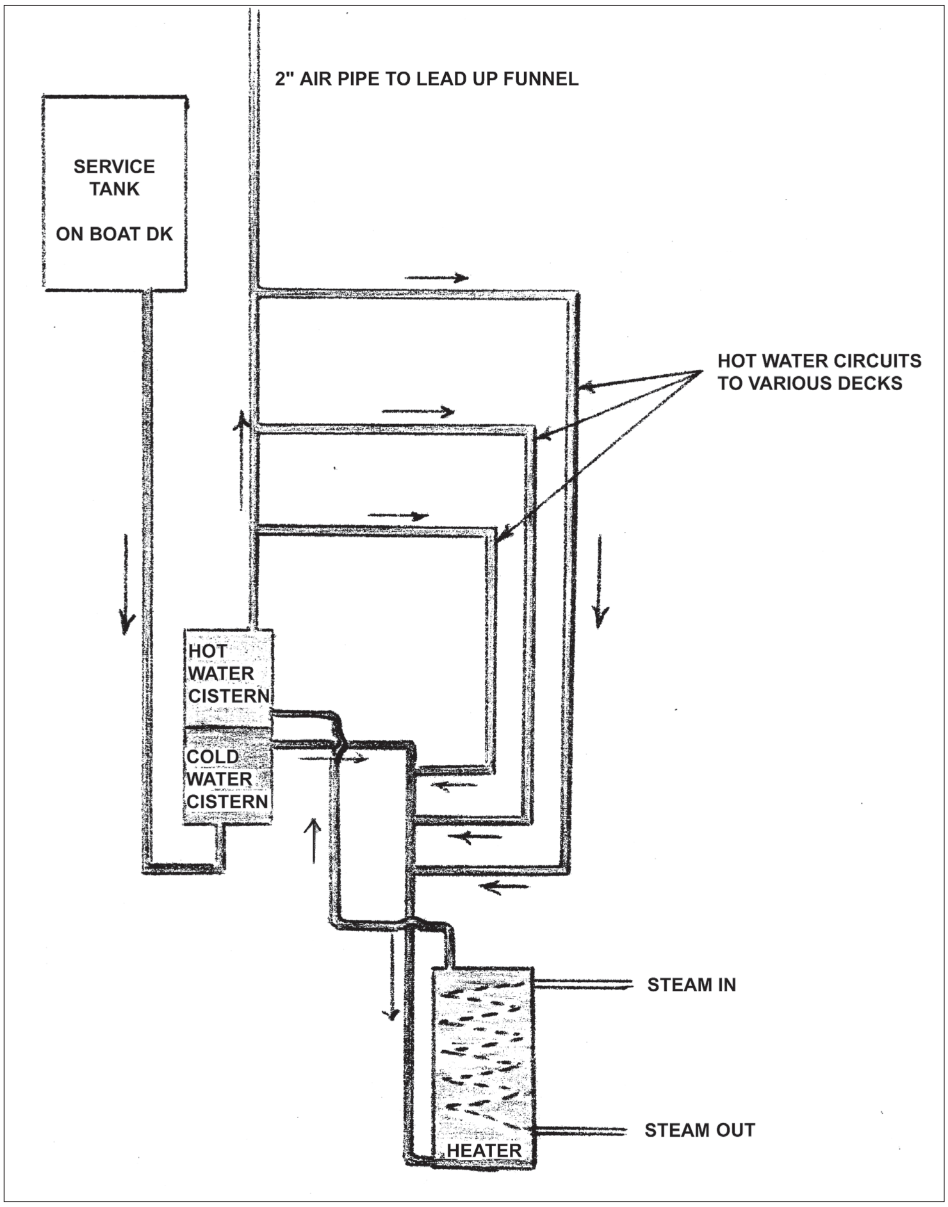

2" AIR PIPE TO LEAD UP FUNNEL
SERVICE TANK
ON BOAT DK
HOT WATER CIRCUITS TO VARIOUS DECKS
HOT WATER CISTERN
COLD WATER CISTERN
STEAM IN
STEAM OUT
HEATER

Fig. 16-25 **Diagrammatic Sketch of Hot Water System** – A simple diagrammatic sketch of the hot-water system used on the *Olympic*-class liners. *(Mark Chirnside collection)*

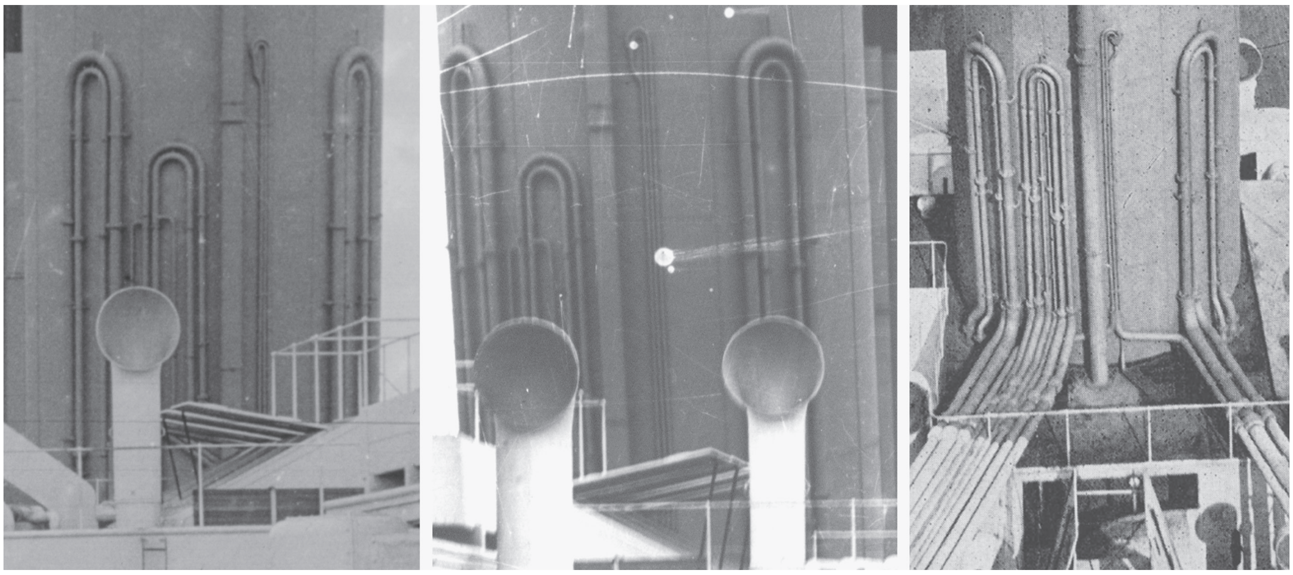


Fig. 16-26 **No.3 Funnel Pipes (1)** – Left and middle images – *Titanic*'s water pipes mounted to aft side of the No.3 Funnel. Right image – *Olympic*'s water pipes after her 1912-13 refit. *Olympic*'s and *Titanic*'s water pipes did not visually match exactly but served the same purposes. The P-shaped pipes allowed for thermal expansion for the hot water systems; pipes of this sort could be found on each of the four funnels. *(All images from authors' collection)*

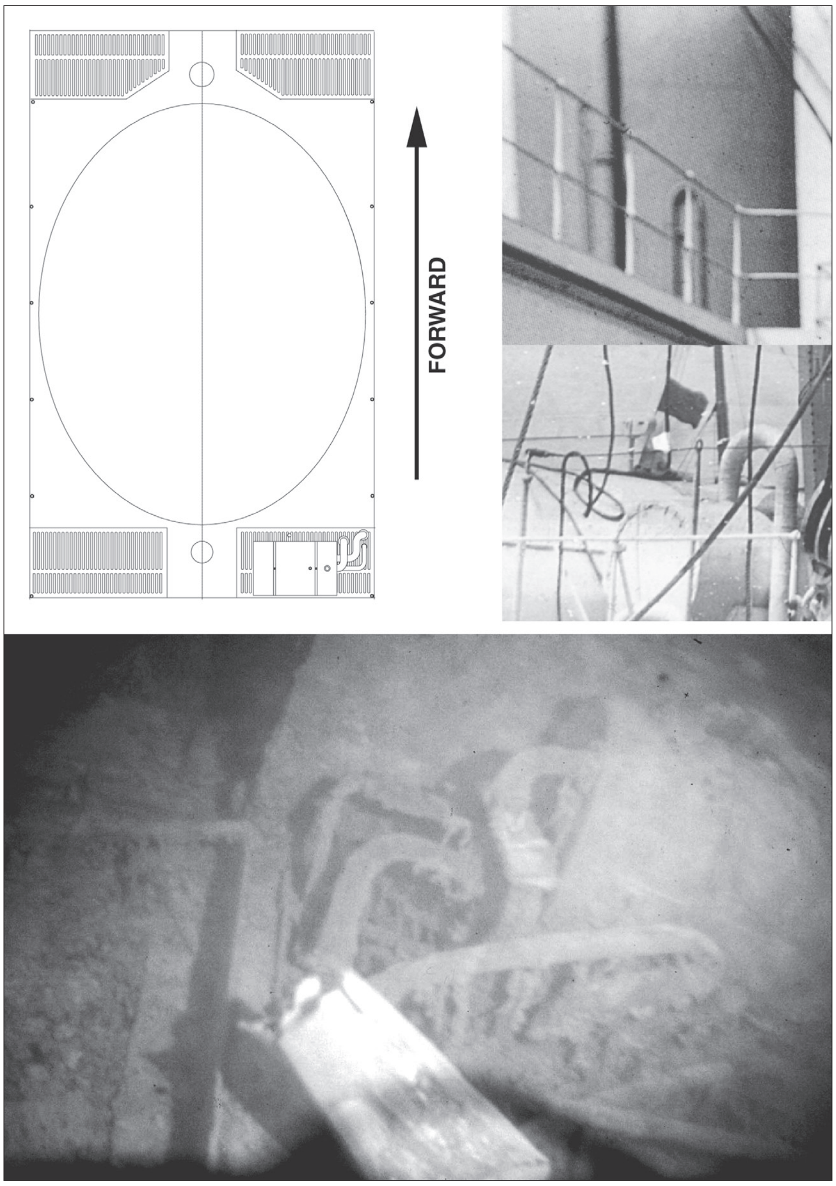


Fig. 16-27 **Washing Water Tank Abaft No.1 Funnel** – The illustration at upper left shows an external washing water tank found on *Olympic* and *Titanic*, mounted on top of the casing aft of the No.1 Funnel. The image at top right shows the U-shaped main of this tank on *Titanic*. The image at center right shows *Olympic*'s tank in the same position. The main feed pipe seen here was different than *Titanic*'s, but the size of the tank was the same for both ships. The image shows the remains of the tank as seen on the wreck. *(Illustration by Bob Read; wreck photograph Steve Rigby collection; all other images authors' collection)*

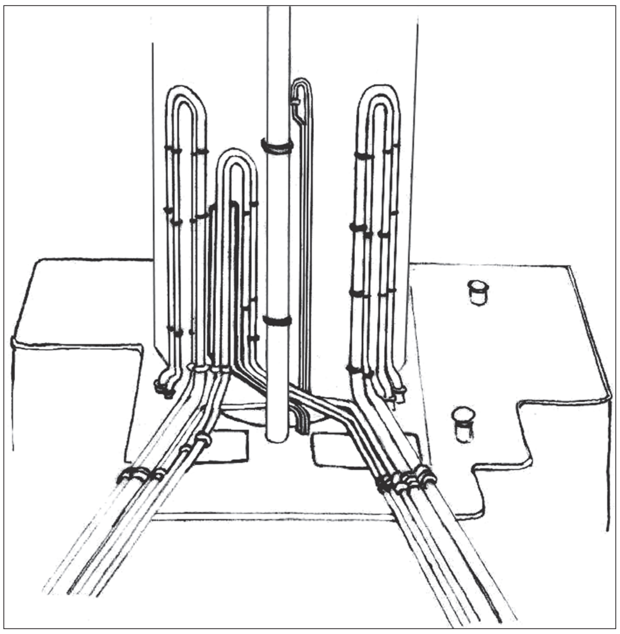


Fig. 16-28 **No.3 Funnel Pipes (1)** – The water pipes mounted to the aft side of the No.3 Funnel. *(Illustration by Bruce Beveridge)*

deckhouse and accompanying First Class staterooms. The washing water tanks were filled periodically from the main tanks at the bottom of the ship (the main tanks being replenished at the end of each voyage) by pumps located in the Reciprocating Engine Room, after being passed through a Railton & Campbell filter. The fresh water was then conducted from the Boat Deck to the various lavatories, pantries, and galleys by a fore-and-aft main and its branches.

Piping to supply hot fresh water for washing purposes was laid out to all the lavatories and to all of the First Class staterooms, including those that were interchangeable between First and Second Class but designated primarily as First Class. In this case, the water passed from the washing water tank on the Boat Deck and was conveyed by a main to heating storage tanks in the boiler uptakes. These 'calorifiers' were heated by steam and regulated by thermostat. The hot water then ran into heat-regulated storage tanks on F Deck. The water, rising with increase

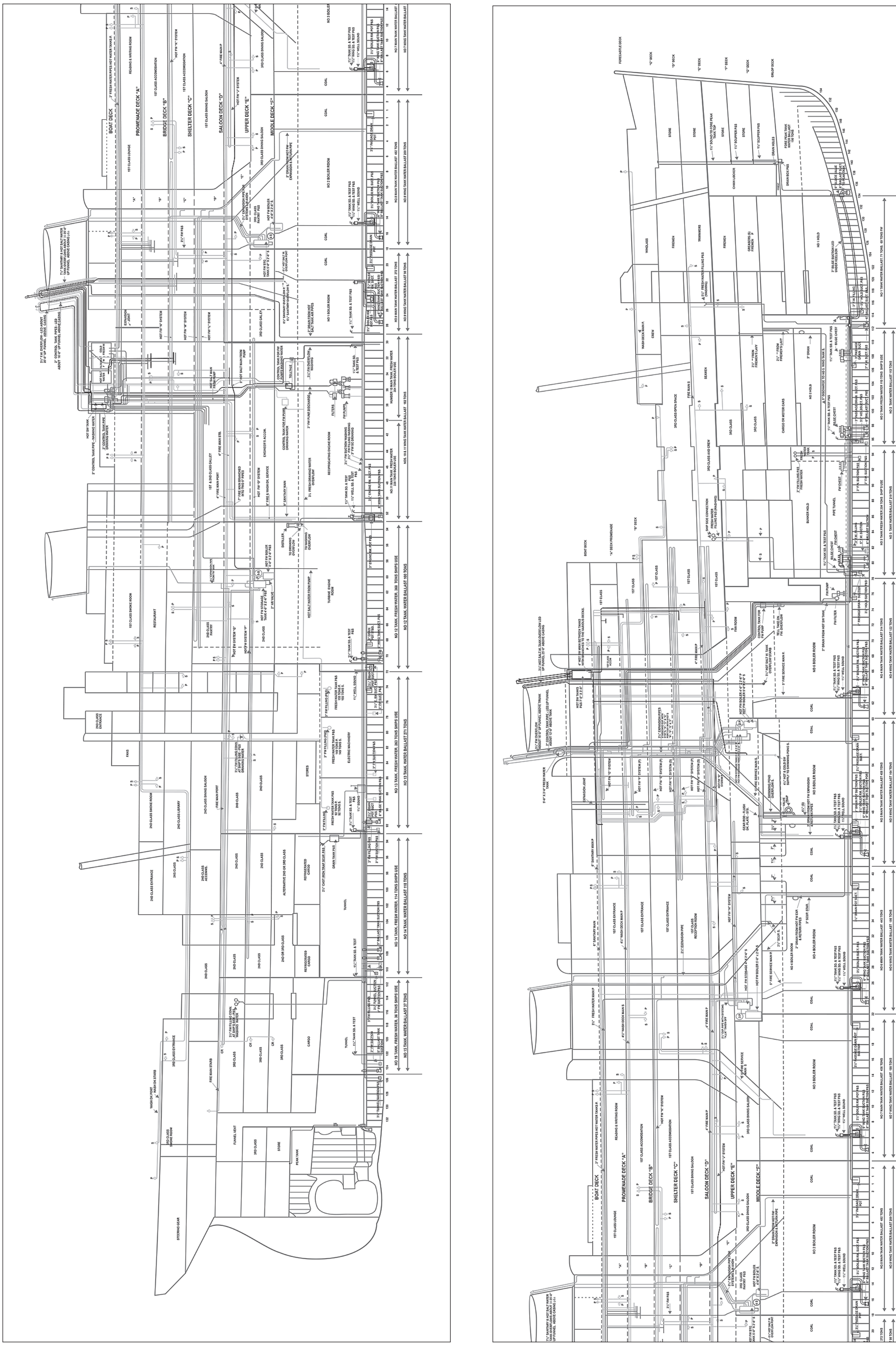

BOAT DECK
PROMENADE DECK "A"
BRIDGE DECK "B"
SHELTER DECK "C"
SALOON DECK "D"
UPPER DECK "E"
MIDDLE DECK "F"
FORECASTLE DECK
ORLOP DECK
STEERING GEAR
PEAK TANK
TUNNEL
TURBINE ENGINE ROOM
RECIPROCATING ENGINE ROOM
ELECTRIC MACHINERY
FILTERS
FW PUMPS
NO 1 BOILER ROOM
NO 2 BOILER ROOM
NO 3 BOILER ROOM
NO 4 BOILER ROOM
NO 5 BOILER ROOM
NO 6 BOILER ROOM
COAL
NO 1 HOLD
NO 2 HOLD
BUNKER HOLD
1ST CLASS SMOKE ROOM
RESTAURANT
1ST CLASS LOUNGE
READING & WRITING ROOM
1ST CLASS DINING SALOON
1ST CLASS RECEPTION ROOM
2ND CLASS DINING SALOON
3RD CLASS DINING SALOON
FRESH WATER TANK P&S 92 TONS P. 92 TONS S.
FRESH WATER TANK P&S 149 TONS P. 149 TONS S.
FRESH WATER TANK P&S 155 TONS P. 155 TONS S.
NO 15 TANK, FRESH WATER, 36 TONS SHIPS USE
NO 15 TANK, WATER BALLAST 37 TONS
NO 14 TANK, FRESH WATER, 114 TONS SHIPS USE
NO 14 TANK, WATER BALLAST 118 TONS
NO 13 TANK, FRESH WATER, 263 TONS SHIPS USE
NO 13 TANK, WATER BALLAST 271 TONS
NO 12 TANK, FRESH WATER, 360 TONS SHIPS USE
NO 12 TANK, WATER BALLAST 100 TONS
NO.11 MAIN TANK FRESH WATER 338 TONS BOILER USE
NUMBER 10 MAIN TANK, FRESH WATER 304 TONS BOILER USE
NOS. 10 & 11 WING TANK WATER BALLAST 182 TONS
NO.9 MAIN TANK WATER BALLAST 272 TONS
NO.9 WING TANK WATER BALLAST 98 TONS
NO.8 MAIN TANK WATER BALLAST 482 TONS
NO.8 WING TANK WATER BALLAST 200 TONS
NO 7 MAIN TANK WATER BALLAST 456 TONS
NO 7 WING TANK WATER BALLAST 198 TONS
NO 6 MAIN TANK WATER BALLAST 445 TONS
NO 6 WING TANK WATER BALLAST 186 TONS
NO 5 MAIN TANK WATER BALLAST 408 TONS
NO 5 WING TANK WATER BALLAST 164 TONS
DRAINS FROM SWIMMING BATH TO BE LED INTO NO 5 WING TANK
NO 4 MAIN TANK WATER BALLAST 314 TONS
NO 4 WING TANK WATER BALLAST 122 TONS
NO 3 TANK FRESH WATER 204 TONS SHIP'S USE
NO 3 TANK WATER BALLAST 210 TONS
NO 2 TANK FRESH WATER 110 TONS SHIP'S USE
NO 2 TANK WATER BALLAST 113 TONS
NO 1 TANK WATER BALLAST. 71 TONS. 69 TONS FW

Fig. 16-29 **Piping Plan** – *Titanic's* piping plan as redrawn by the author from the original. The tank vents and steam fire-extinguishing pipes have been omitted in order to permit a clearer depiction of the water systems. *(Illustration by Bruce Beveridge)*

of temperature, passed into a rising main terminating above the Boat Deck with overflow pipes. From the rising mains, there was a series of branch mains or 'loops' connected with all lavatories, etc. in each compartment on the decks immediately above the branch main. The latter were suspended under the deck. By this means the water was hottest at the point of discharge, so there was no need to run the water from the tap until hot water was received. As a result, there was less waste than with the more common gravity-feed systems. A traveler on *Olympic* during one of her first voyages observed that 'the hot water service is clean and quick'.

The tanks of hot fresh water on F Deck were located in close proximity to the Turkish Baths and no doubt received steam from the same reduced-pressure supply. Hot drinking water could also be obtained from the many service rooms or pantries throughout the accommodations, where it was maintained and heated within cylindrical copper tanks fitted with steam coils.

The process of pumping water up to the Boat Deck required a large number of main pipes. These pipes pierced the tops of the boiler casings in several locations and were visible mounted on the exterior plating of the funnels. The pipes extended upward above the fidley decks and then looped back down to feed their designated supply systems. The water, by being pumped up to a level above the tanks, created a water column in each pipe that created water pressure higher than that which would have been realized by gravitational force alone straight from the tanks.

Feed mains could be seen on the forward and after sides of the No.1 Funnel and the after side of the No.3 Funnel; these gave the visual appearance of an inverted 'U'. The pipes that gave the appearance of the letter 'P' were the hot water overflows previously described. The overflow water from hot water pipes was redistributed back into the system.

The water tanks initially installed aboard *Olympic*, as recorded in Harland & Wolff's specification notebook, give a reasonable insight into *Titanic*'s configuration, allowing for the omission of the sanitary tanks. The Tank Rooms on the Boat Deck contained a 1,350-gallon washing water tank, a 1,350-gallon filtered fresh water tank[11] and a 780- and a 620-gallon hot salt water tank. Each of the two hot salt water tanks located within the boiler casing forward of the No.1 Funnel above the level of the Boat Deck held 310 gallons. The washing water tank located on top of the boiler casing aft of the No.1 Funnel held 220 gallons. The hot fresh water arrangement located within the boiler casings consisted of three 125-gallon and two 160-gallon storage tanks, while their accompanying boilers consisted of three 125-gallon and two 160-gallon tanks.[12]

Notes

1. It is important to remember that 'floors' are *vertical* steel plates within the ship's bottom. The term does not refer to the steel plates that form the top of the double bottom.
2. The No.5 Wing Tank was also the reservoir for the overflow of the Swimming Bath and specific other scuppers and drains within the ship.
3. According to Naval Architect Edward Wilding's calculations, 16,000 tons of sea water entered the ship in the first forty minutes following the collision, far beyond the capacity of all of *Titanic*'s pumping systems combined, which totaled 1,700 tons per hour.
4. No.1 Boiler Room was not fitted with ash ejectors. These five pumps are covered in more detail in Chapter 15 of this volume.
5. Captain Rostron of the *Carpathia* made good use of this continuous overboard discharge by ordering oil to be poured down the water closets of the *Carpathia* upon reaching *Titanic*'s lifeboats. Oil, which is lighter than water and will lie on top of it, tends to moderate the choppiness of the water around the ship, making it easier to control a boat coming alongside.
6. The purpose for the additional looped standpipes on the various funnels will be dealt with further on in the section on the fresh water supply.
7. White Star Line regulations required that decks be washed down and as dry as possible by 8.00 a.m.
8. *Olympic*'s auction book from 1935 shows 4in-diameter hoses at lengths from 50ft on up, however 30ft lengths of 2½in-diameter leather hose was also common on aboard ship.
9. Unlike today, the type of matches carried by most people were friction matches, which could be struck almost anywhere and were therefore much more hazardous.
10. *Titanic*'s passengers were given water '*au naturel*' as one period source cited.
11. The filtered fresh water and washing water tank were actually two tanks in one divided in the center.
12. Specifications on tanks were taken from 1911 *Olympic* specifications and were compared to those on *Titanic*'s water system plan which does not give tank capacities. The location and purpose of the many small water storage and supply tanks fitted aboard *Titanic* was obtained from a recently discovered blueprint of the original Harland & Wolff plumbing plan. In instances where the sizes and capacities for these tanks were not noted on the drawing, these figures have been obtained through careful comparison with the tank data in the 1911 *Olympic* specifications.

Chapter 17

Electric Generating Plant, Wiring, Elevators and Electrical Fittings

While electric lighting aboard ships was once considered a luxury, by *Titanic*'s time it had become a necessity both for comfort and safety, as it was superior to oil lamps or any other systems of lighting. The electrical installation aboard *Titanic* was very elaborate and extensive, as electrical power was used for many devices and small motors in addition to general lighting. Except for the propelling machinery, electrical generating equipment and galley ovens, nearly everything from potato peelers to cargo cranes ran on electricity. For this reason, *Titanic* had, in addition to a very large, steam-driven main generating plant, an auxiliary (emergency) generating plant capable of powering most of the ship's essential equipment as well as the ship's navigation and emergency lighting.

Titanic's central generating station, called the 'Electric Engine Room',[1] was situated between the wing propeller shafts in a separate watertight compartment about 63ft long and 24ft high, immediately abaft the Turbine Engine Room at the Tank Top level. The main generating plant consisted of four 400-kilowatt dynamos manufactured by W. H. Allen, Son & Co. of Bedford. In total, these produced 16,000 amps at 100 volts DC – greater than the output of many large municipal stations of the era.[2] The four sets were arranged in pairs, with the crankshafts of each pair in line fore-and-aft and the stop valves of each located inwards. One pair was located on the starboard side of the compartment; these were numbered Dynamos 1 and 2, 1 being the forward set. Opposite this pair on the port side were Dynamos 3 and 4, 4 being the forward set. They were situated with a gangway running fore-and-aft between them. A common platform by which access was gained to the cylinder covers, etc., extended right across the two units of one pair, the ladder being placed in the gangway between the two units.

The emergency generating sets, also steam-driven, consisted of two 30-kilowatt dynamos and were available for use in any situation which might disrupt the supply of electricity from the main generating sets. These were situated in a recess or 'flat' in the turbine engine casing on D Deck, well above the water line and five levels above the Electric Engine Room.

Although improvements in electrical gear for ship work continued at a rapid pace in the first quarter of the twentieth century, the systems of wiring remained almost unaltered. On *Titanic*, as with all shipboard electrical systems, precautions were necessary to safeguard the apparatus and maintain the efficiency of the installations against moisture, salt spray and vibration. Electrical work on ships was a special class all in itself, requiring skilled

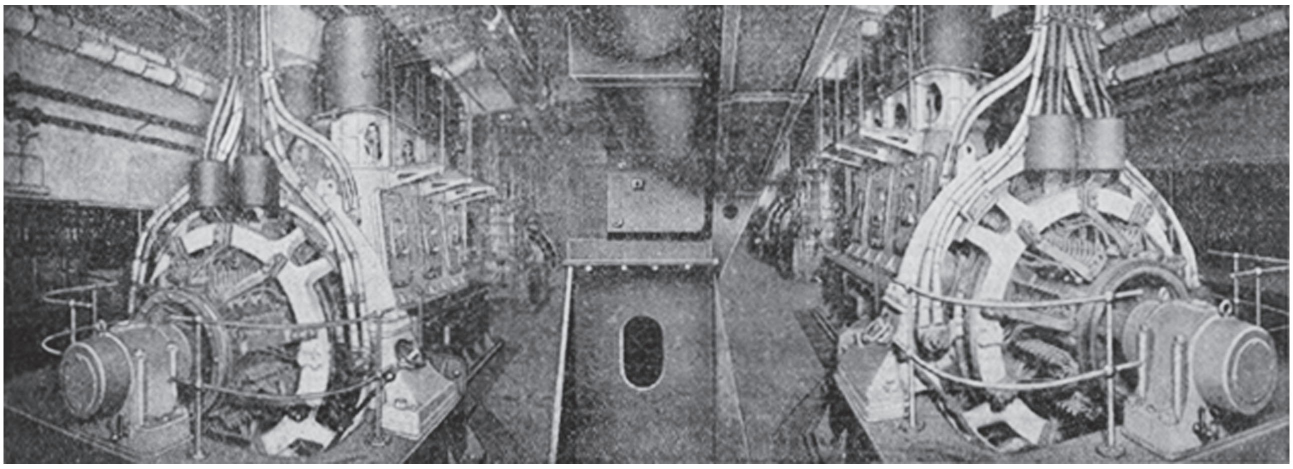


Fig. 17-1 **An Overall View of the Electric Engine Room.** This view looks forward along the lower level. (The Electrician*/Authors' collection)*

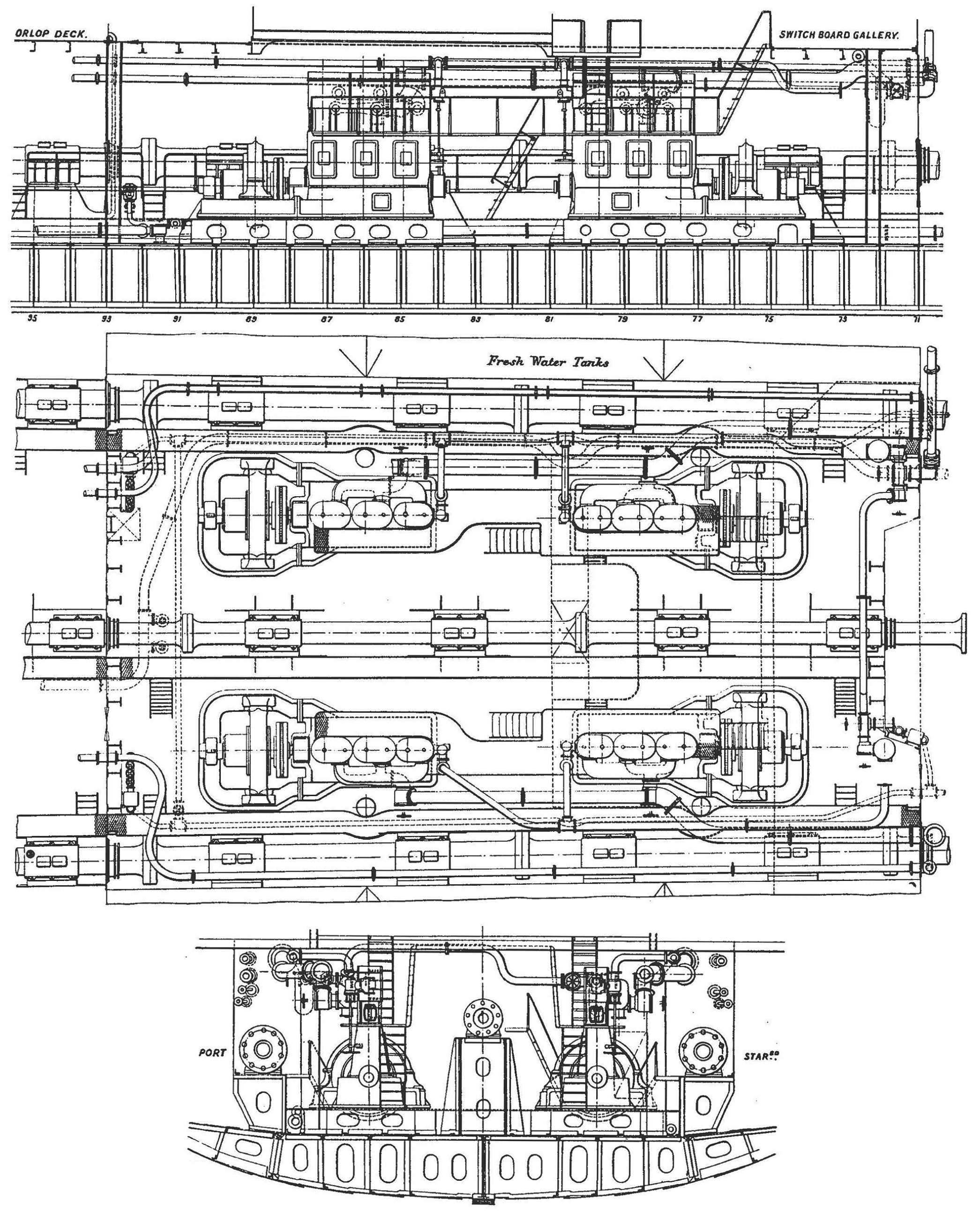


Fig. 17-2 **Elevation, Plan and Sectional Views of Electric Engine Room.** (The Engineer/ *Authors' collection*)

and experienced men, as shipboard requirements were totally different from those on land. In addition, the system of wiring itself differed entirely from what was commonly seen on land. *Titanic* utilized the single-wire, or 'ship return', system which used the steel hull of the vessel as a conductor instead of the common two-wire system that was used on American-built ships. With the single-wire system, when a conductor was carried throughout a ship and a connection was made to one terminal of each electric light fixture, the corresponding terminal on the other side was connected to the ship's body. As the ship's body was immersed in the sea, the connection became essentially an 'earth' connection – in other words, the electrical terminal on one side was 'earthed', or grounded. Connections were made with the skin of the ship wherever required – for example, where fittings were not mounted directly to a steel beam. Low-return wires were carried back from the bow to abaft the Turbine Engine Room, and bonded in such a way as to avoid stray currents.

The single-wire system was carried out with distribution boards which obviated the necessity for joints in the cables, all connections being made by looping in either at the distribution boards or at the fittings. The number of fuses varied from three to eight according to power requirements. A distribution board served a particular group of lights such as those in a dining saloon or in a block of staterooms, crew's quarters or officers' rooms. Where any compartment had more than one light, it was advantageous to divide the lights

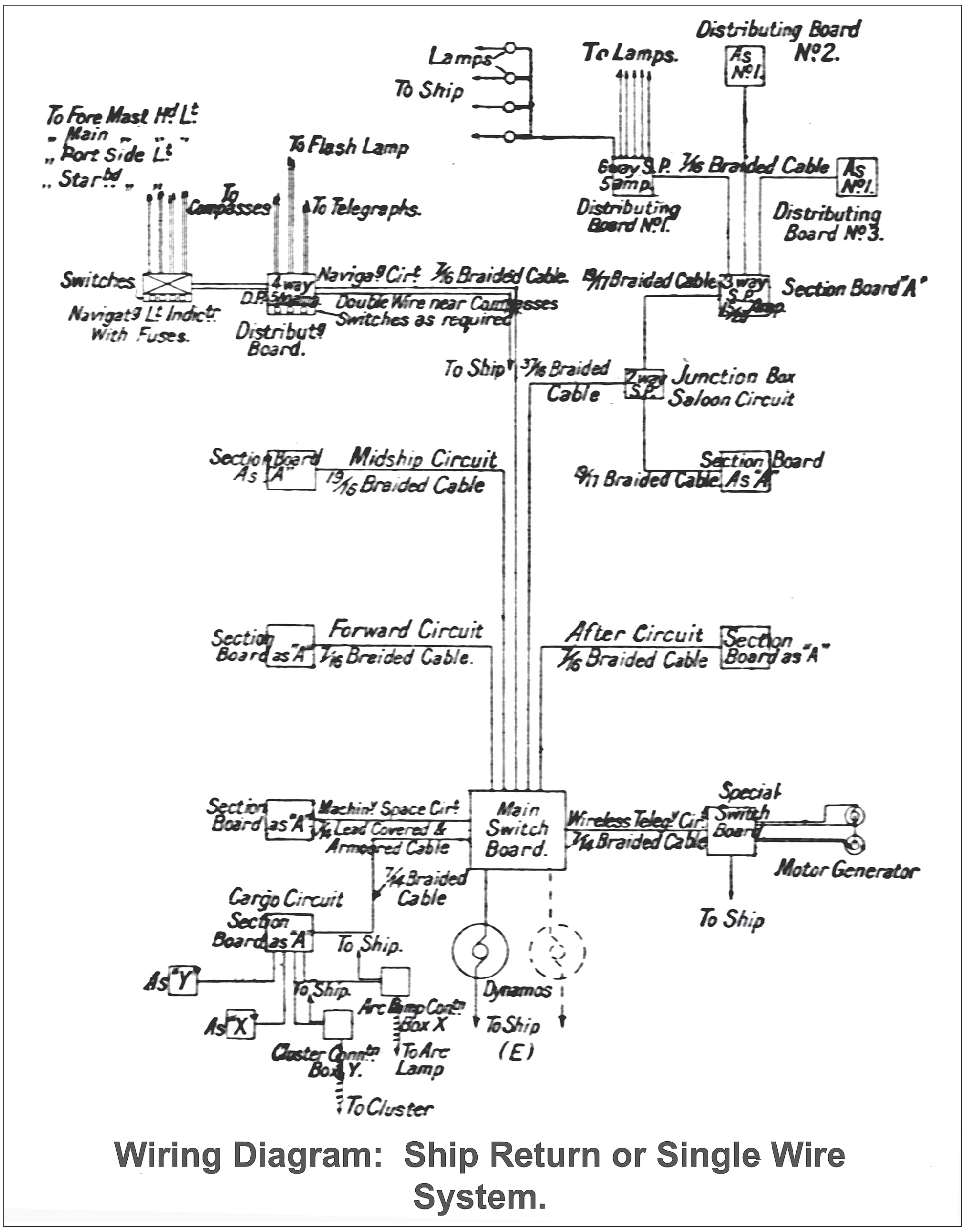

Distributing Board No2.
As No1.
Lamps
To Lamps.
To Ship
To Fore Mast Hd Lt
" Main " "
" Port Side Lt
" Starbd "
To Flash Lamp
To Compasses
To Telegraphs.
6 way S.P. 5 amp.
7/16 Braided Cable
As No1.
Distributing Board No1.
Distributing Board No3.
Switches
Navigatg Lt Indictr With Fuses.
4 way D.P. 5 amp
Distributg Board.
Navigag Cirt 7/16 Braided Cable.
Double Wire near Compasses
Switches as required
19/17 Braided Cable
3 way S.P. 15 Amp.
Section Board "A"
To Ship
37/16 Braided Cable
2 way S.P.
Junction Box Saloon Circuit
Section Board As "A"
Midship Circuit
19/16 Braided Cable
9/11 Braided Cable
Section Board As "A"
Section Board as "A"
Forward Circuit
7/16 Breided Cable.
After Circuit
7/16 Braided Cable
Section Board as "A"
Section Board as "A"
Machiny Space Cirt
7/14 Lead Covered & Armoured Cable
Main Switch Board.
Wireless Telegy Cir.
7/14 Braided Cable
Special Switch Board
Motor Generator
To Ship
7/14 Braided Cable
Cargo Circuit Section Board as "A"
To Ship.
As "Y"
As "X"
To Ship.
Arc Lamp Contn Box X
Cluster Conntn Box Y.
To Arc Lamp
To Cluster
Dynamos
To Ship (E)
Wiring Diagram: Ship Return or Single Wire System.

Fig. 17-3 **Ship Return System** – A basic schematic of a single-wire, or 'ship return,' electrical system.

and put them on two fuses so that in the event one fuse blew, the entire compartment would not be in total darkness. Controlling switches were fitted on or beside a fuse board to control all the lights fed off that particular board. This gave the crew the option of switching the current on or off completely in any section of the ship. Outside decklamps, for example, were routinely turned off late at night.

Main electric generating sets

The four main electric dynamos, or 'generating sets', worked in parallel.[3] Power requirements were such that at any given time, one machine supplied electricity for the lighting of the ship, two more dealt with the demands for power or heating and the fourth machine was a standby.

Each dynamo could be stopped, started or varied in speed independently of the others by the Electrician in charge, depending on the electrical load at any given time or the need to change any given dynamo from standby to active status. The transmission of instructions from the switchgear deck to the engine attendant was accomplished by use of an illuminated signal device located in the center of the Electric Engine Room where it could be easily seen and read from both sides. This could be operated from a control knob on each of the dynamo control gears.

On turning the knob to the instruction to be given and pressing it, the corresponding sign was illuminated and a bell was rung to alert the attendant. The signs reading 'START', 'RAISE SPEED', 'LOWER SPEED' and 'STOP', combined with the number of the machine to which the signal applied, were visible in white letters

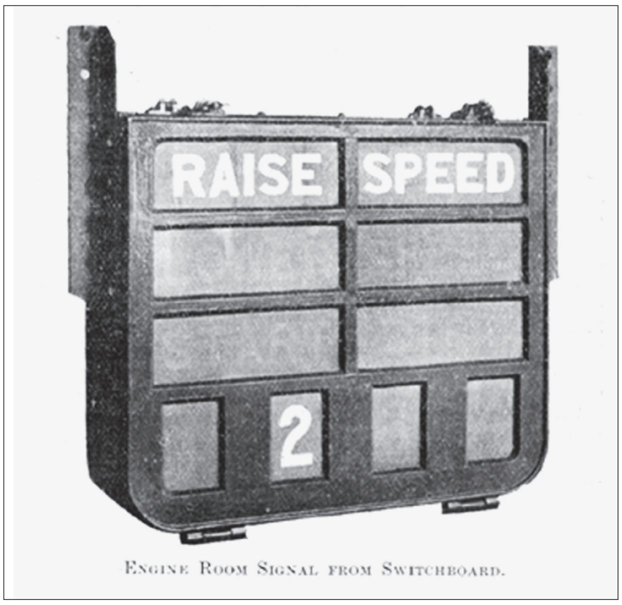


Fig. 17-4 **Illuminated Signal Device**. *(*The Electrician*/ Authors' collection)*

on a red background when the lamps were illuminated.

Each dynamo was driven by a set of enclosed high-speed reciprocating steam engines operating at an average of 325RPM, at which speed they indicated 580HP. Engine speed was monitored on tachometers driven by silent chains manufactured by the Hans Renold company. The engines were of the three-crank, three-cylinder, compound forced-lubrication type with the crankshafts and connecting rods enclosed in a crankcase. The engines had one high-pressure cylinder 17in in diameter and two low-pressure cylinders 20in in diameter, each with a stroke of 13in. Steam was supplied at 185psi and was exhausted either into the surface heater while at sea or into the auxiliary condenser while in port. The steam for the dynamo engines was supplied from the main boilers in any of three boiler rooms, but, as the main boiler steam pressure was higher than was required for the dynamo engines, it was reduced to 185psi by means of a special reducing valve. The single-ended boilers in Boiler Room No.1 supplied steam to the main generator sets while *Titanic* was in port. At sea, steam was supplied by two boilers in each of Boiler Room Nos 2 and 4. Additional details about the steam supply to the main and emergency generating sets may be found in Chapter 15 of this volume.

Each engine was coupled directly to a continuous-current, compound-wound dynamo of the ten-pole type fitted with interpoles. The dynamos were of the direct-current type and were similar to those in use in shore power stations of the time. There were four ammeters, one for each dynamo, each reading up to 5,000 amps and indicating the load on the machine to which it was wired. There were also four integrating wattmeters which recorded the number of units generated by the dynamos. For guidance in coupling or uncoupling the sets in parallel, four revolving voltmeters were mounted on a stand between the dynamo pillars; these indicated the power at the lighting and power bus bars and any individual dynamo.

The field magnets in the dynamos were annealed cast steel of high permeability, cast in halves and divided on a horizontal plane. The ten main poles were cast in one piece with the yoke ring and were fitted with laminated pole shoes. The interpoles were secured by bolts to facings on the inner surface of the yoke ring. The series coils of the interpoles and commutating poles were of flat copper strip, wound on edge. Care was taken by the designers to ensure ample ventilation around all the windings and to provide ease in both disconnection and replacement of the different sections.

The armatures were of the slotted drum type, built up of mild-steel plates on a cast-iron hub, the 'former-wound' coils being of flat copper strip. The commutators, which had to deal with an exceptionally large current, were of massive construction and designed to ensure only a moderate degree of heating. The brushes were made of carbon and graphite, a combination which provided good conductivity as well as low friction. This preserved the surfaces of the commutators in good condition for long periods. For instances where the commutators needed servicing, an emery grinder was provided.

The main voltmeters, which were also used for paralleling, were mounted on a cast-iron pillar amidships between the main dynamo control gear. The voltmeters themselves were mounted in pairs, each pair arranged

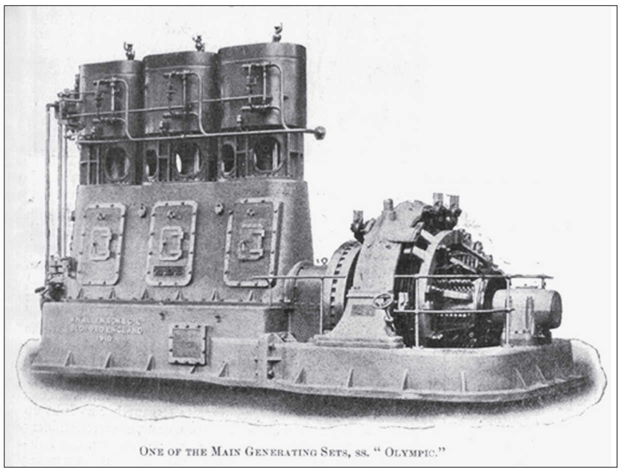
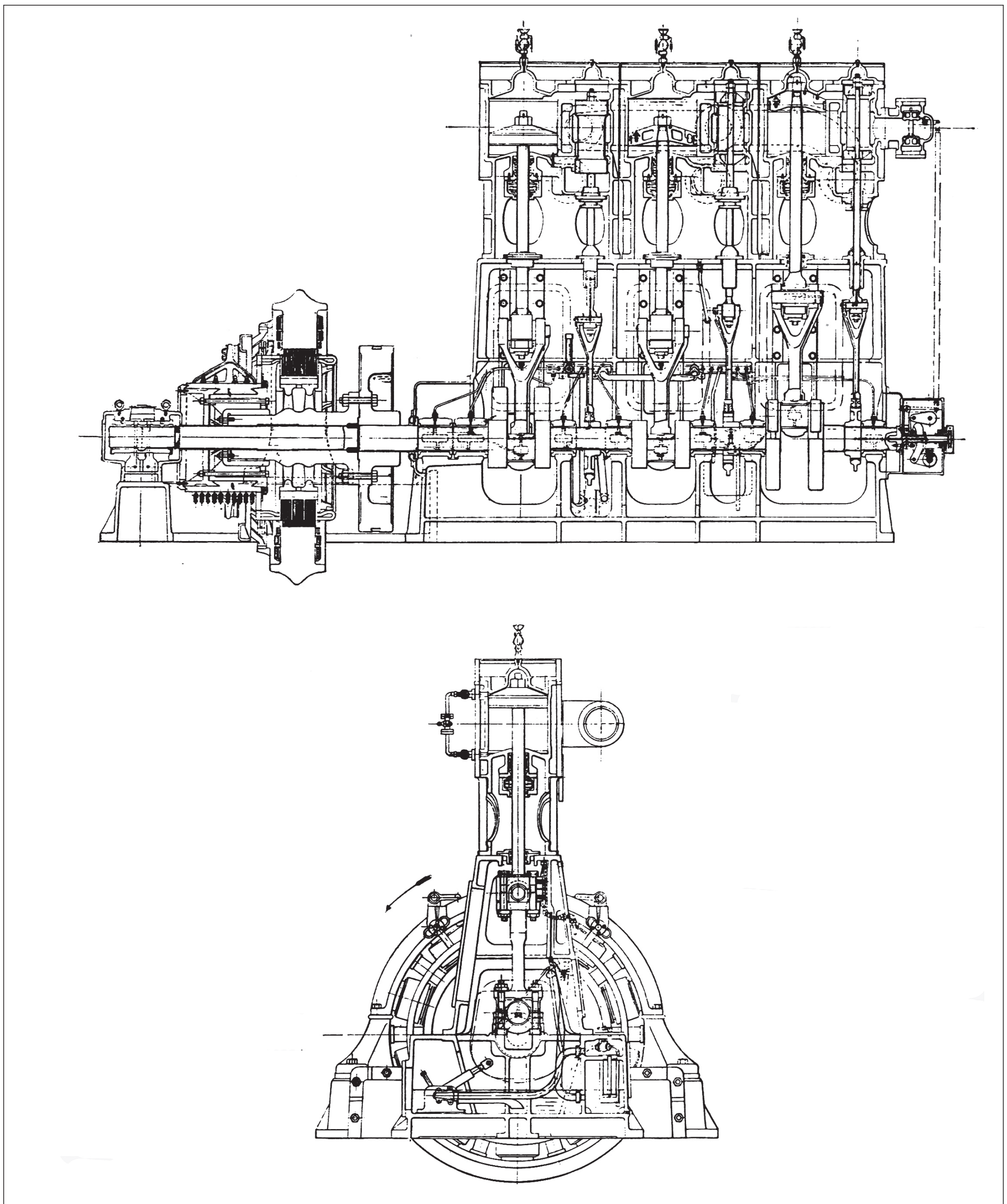


Fig. 17-5 **Main Generating Set** – One of the main generating sets of the type used on *Olympic* and *Titanic*. In 1912, these sets were still very often referred to as 'electric dynamos.' *(*The Electrician*/Authors' collection)*



Cross Section and Section Elevation of one of the main generating sets

Fig. 17-6 **Cross-Section and Sectional Elevation of one of the Main Generating Sets**. *(*The Shipbuilder*/ Authors' collection)*

so that they could swing around through 220°. The two outside instruments indicated machine voltages, while the two center instruments indicated bus bar voltages, the former being controlled from the plugging arrangements on the main dynamo panels, and the latter on the voltmeter pillar itself.

The voltmeter plugs were of the three-pin type and were made so that the machines could not be put in parallel onto any one instrument. The third pin on each voltmeter plug was connected to the lamp circuit, automatically illuminating a sign so that the insertion of a voltmeter in any socket caused a lamp on the voltmeter pillar to be illuminated, indicating to the operator to what the voltmeter was connected.

All of the main generating switches, shunts and connections were carried on steel bars insulated with hard micanite.[4] The supporting bars were, in turn, carried on a steel-frame casting, and the whole gear for each machine was enclosed in a steel casing supported on a cast frame.

Emergency generating sets

In addition to their much smaller size, the pair of emergency generating sets differed from the main sets in that the engines were of the two-crank, two-cylinder compound type, and the dynamos were not fitted with

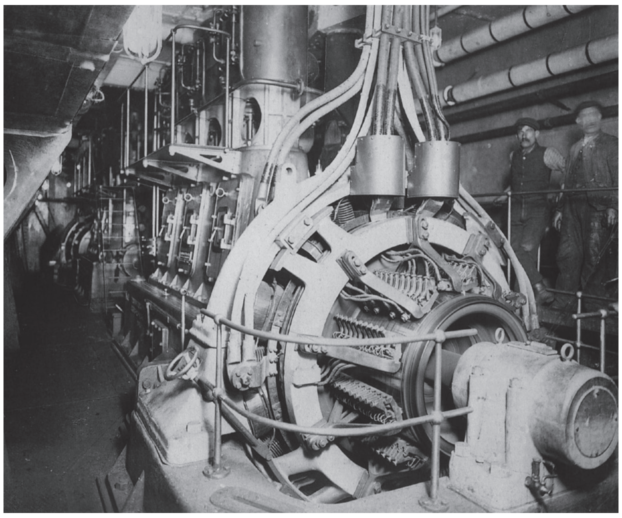


Fig. 17-7 **Main Generating Sets Installed in the Electric Engine Room.** *(H&W/Authors' collection)*

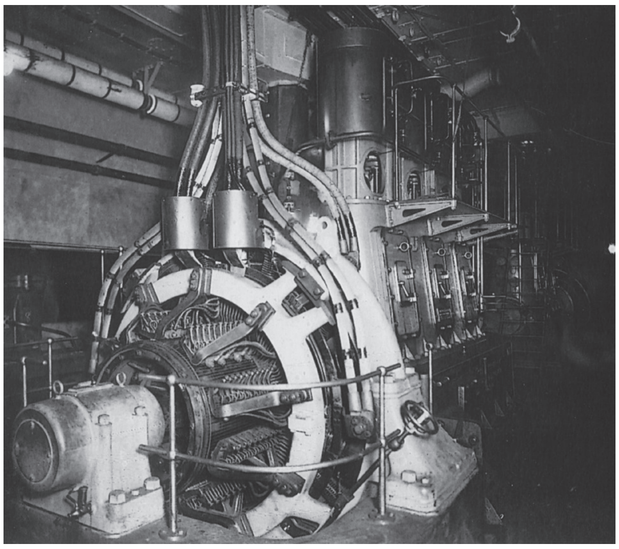
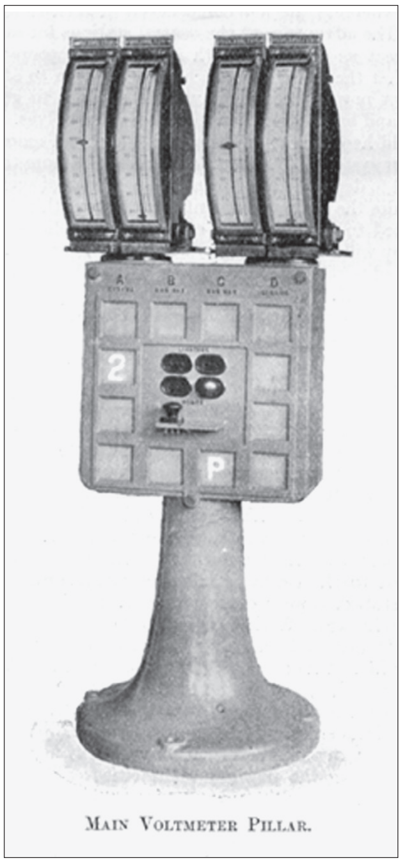


Fig. 17-8 **Main Generating Set** – Alternate View. *(H&W/Authors' collection)*



Main Voltmeter Pillar.

Fig. 17-9 **Main Voltmeter Pillar**. *(*The Electrician/*Authors' collection)*

commutating poles. Each engine had a high-pressure cylinder of 9in in diameter and a low-pressure cylinder of 12in in diameter, with a 5in stroke and running at 380RPM. The engines of the emergency sets were supplied with steam from a pipe which was led along the beams in the working crew passageway on E Deck, feeding from any one of three separate pipes that ran above the watertight bulkheads to Boiler Room Nos 2, 3 and 5. The emergency dynamos were engaged every night after midnight to supply 'police' lighting in the various passages and stairways throughout the ship, as well as emergency lights in the staterooms. It was recommended by the Board of Trade that all compartments which were lighted by electric light alone have an oil or candle lamp placed at the exits, and kept burning during the night, in case of accident or break down. However, the Board of Trade made departures from this rule in cases where the ships had emergency dynamos as were fitted to the *Olympic*-class liners.[5]

Emergency lights deriving current from the emergency dynamos were on circuits separate from those of the main lighting, and were placed at intervals in the passages, public rooms, and compartments throughout the vessel. There were enough of these lights to provide limited illumination throughout the ship even if the main dynamos became completely inoperative.[6]

In addition to supplying electrical power for the emergency lighting circuit, the emergency sets were of sufficient capacity to supply the Marconi apparatus, the steaming lights (running lights), all lights on the Bridge including the Navigating and Chart Rooms, Wheelhouse, telegraphs and compasses, Morse lamps and boat winches. Additionally, the ship's gangway lamps, cargo lamps and arc lamps had alternate connections to the emergency circuit. A special switchboard was fitted beside the emergency dynamos so that the emergency plant could be run even if the Engine and Boiler Room(s) not needed to supply steam to the sets were flooded.

Main switch gear

From the main dynamos at the Tank Top level, the current was conveyed to the main switch gear, located in the aft end of the switchboard gallery at the Orlop Deck level above the forward end of the Electric Engine Room. The switch gear, or dynamo control switches, permitted the Electrician in charge to couple or uncouple the individual dynamos from the feeder switchboard from which power was distributed to all areas of the ship. Heavy rubber-insulated cables of 1½sq. in sectional area and 2¼in diameter carried the current from the dynamos to the switchgear.

There were two main circuits for the ship, one for lighting and one for power (including heating). The main switches for each of these circuits were four-way switches, meaning that any dynamo could be switched to either the power or the lighting circuit. With this arrangement, when only a light load was on – for instance, at night when the demand for power was reduced – the whole load on the power circuit could be switched on to any one dynamo, permitting the other dynamo to be taken off-line and placed on standby.

Equalizing switches were in line between the dynamos and the switchgear in order to minimize and equalize the resistance between the dynamos. These switches were located above the dynamos at the Orlop Deck Level, as equidistant as possible from the four dynamos. There was a power and lighting equalizing switch for each, and these were mechanically operated from the switchgear deck by levers interlocked with the other main switchgear so that no machine could be connected to a power or lighting bus bar until after its equalizing switch was connected to the correct circuit.

The main switchgear was manufactured by Dorman & Smith of Salford, Manchester. It consisted of four sets of main switchgear arranged in pairs, each set controlling the output of one of the four main dynamos. From the switchgear, the current led to a main feeder switchboard that distributed power throughout the ship. The Electrician in charge faced the switchgear machinery when operating it. When he desired the Electrician below to stop, start or adjust the speed of a particular dynamo, he could communicate his instructions by means of electrically illuminated signals as previously discussed.

Each set of switchgear machinery consisted of a unit with a row of five handle levers in front, interlocked to ensure correct operation. The two outer handles were connected mechanically with the lighting and power equalizing switches, respectively, and were interlocked so that they had to be closed before the next handles, which operated the lighting and power main bus-bar selector switches, could be worked. The central handle was for closing and gripping the circuit breaker, and was also interlocked with the selector switch handles, so that the circuit breaker could only be closed and gripped when the selector switches were both in the 'OFF' position.

Figure 17-12 shows the complete switchgear machines of dynamos 1 and 2. Visible at the side of the casing are two devices for tripping the main circuit breaker; the top one closed the electrical circuit of the trip coil and the lower one mechanically tripped the toggle grip and lifted the trigger. On the right-hand side of each gear was a small panel with the fuses of the pilot lamps, wattmeter, shunt, etc. On the upper right-hand side was the Engine Room signal knob.

The selector switches were massive with a long rubber contact to avoid dirt being squeezed in under the contact faces. The sectional area was 13.7sq.in and the contact surface 21sq.in. The link connecting these switches to the operating lever handle was arranged so that minimal effort was required on the part of the switchboard attendant. These switches were compactly constructed for such heavy gear, being identical with the main selector switches in capacity and construction. The contacts were combined with the equalizing bus bar so that the minimum amount of space was taken up;

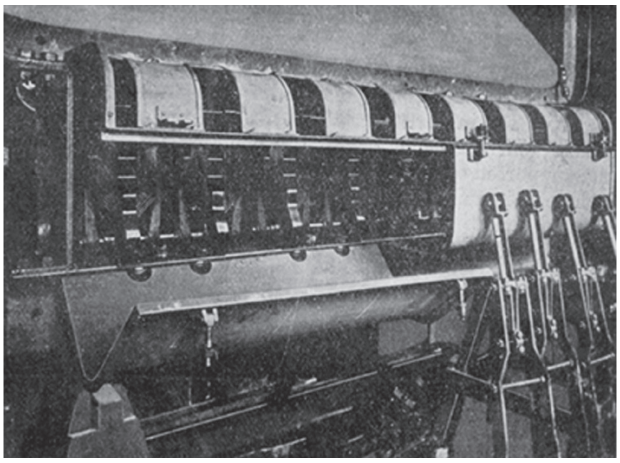
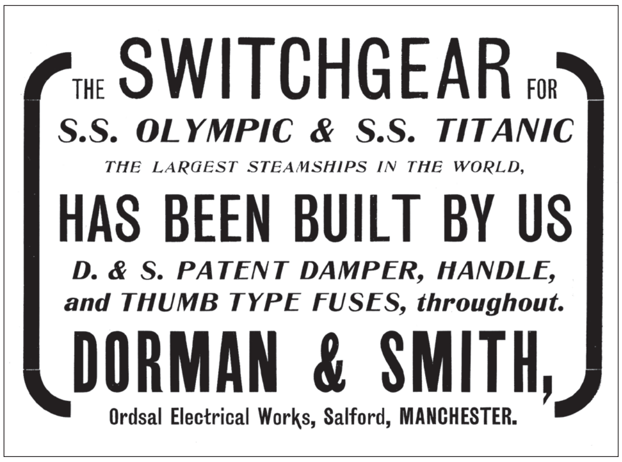


Fig. 17-10 **Equalizing Switchgear**. *(*The Electrician*/Authors' collection)*



THE SWITCHGEAR FOR

S.S. OLYMPIC & S.S. TITANIC

THE LARGEST STEAMSHIPS IN THE WORLD,

HAS BEEN BUILT BY US

D. & S. PATENT DAMPER, HANDLE, and THUMB TYPE FUSES, throughout.

DORMAN & SMITH,

Ordsal Electrical Works, Salford, MANCHESTER.

Fig. 17-11 **Advertisement for Dorman & Smith Switch Gear**. *(*The Shipbuilder*/Authors' collection)*

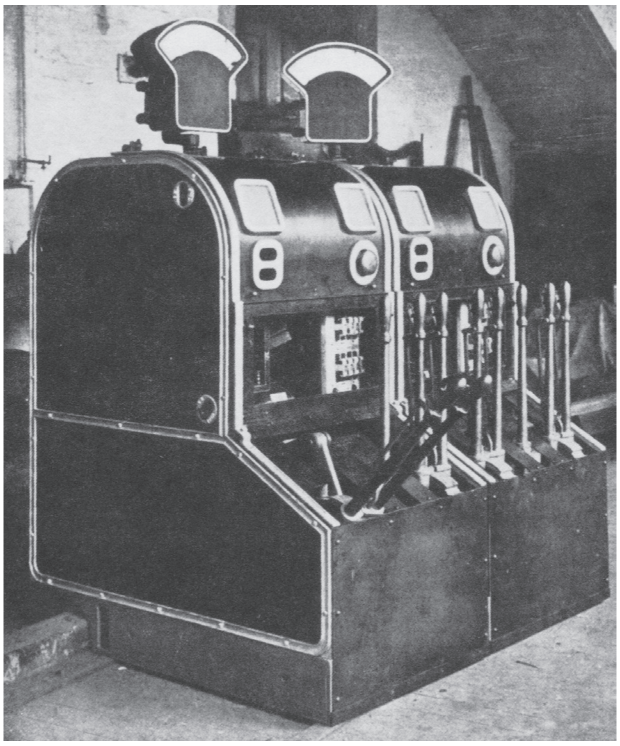


Fig. 17-12 **Switchgear of Dynamos 3 and 4**. *(*The Shipbuilder*/Authors' collection)*

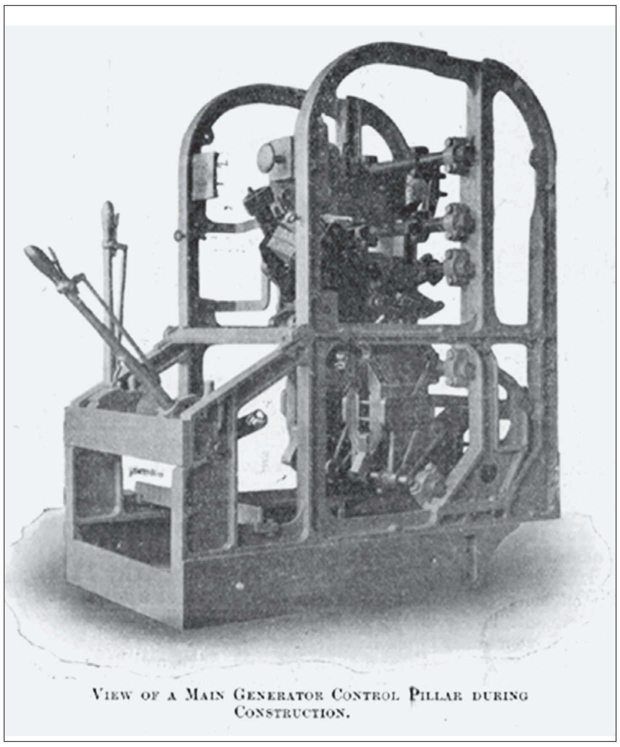

View of a Main Generator Control Pillar during Construction.

Fig. 17-13 **Switchgear Under Construction**. *(*The Electrician*/Authors' collection)*

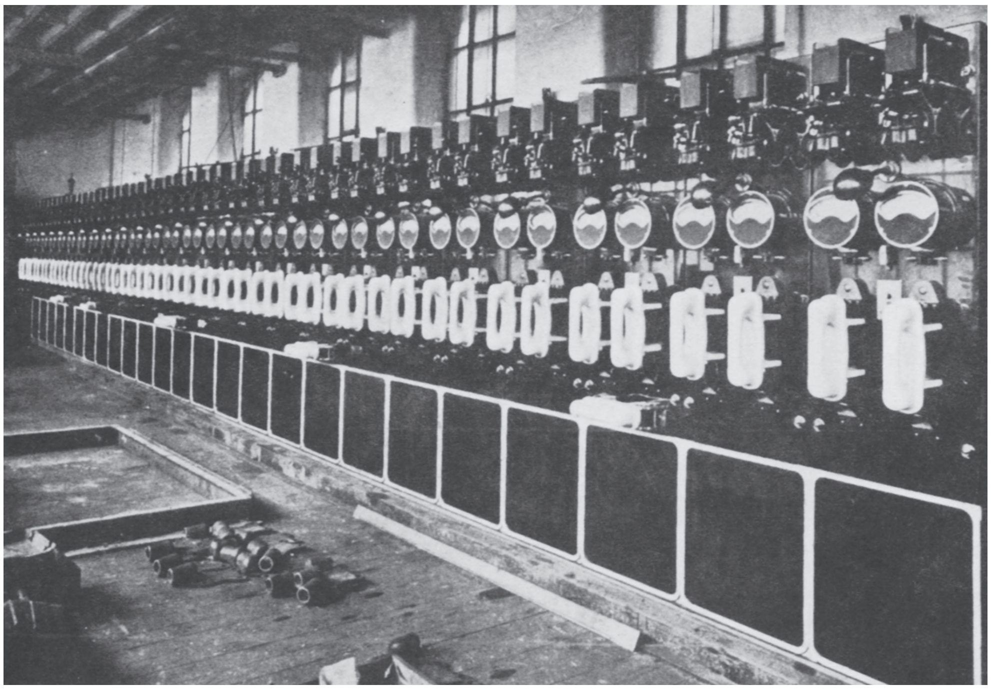


Fig. 17-14 **Main Feeder Switchboard** – The main feeder switchboard in Harland & Wolff's Electrical Shop before installation. *(*The Shipbuilder*/Authors' collection)*

the eight switches and two bus bars were carried on a massive steel frame, and were insulated with micanite. This frame was bolted and stayed to the ship's structure. A sheet-steel casing was built around the eight switches to protect them and formed part of the steel foundation frame.

Pilot lights were provided as follows: on the switchgear machine housing of any dynamo that was online, the dial of the ammeter was illuminated; on closing a circuit breaker, two pilot lights across the machine illuminated the inside of the casing containing the switchgear; on closing either a power or lighting selector switch, two more pilot lights illuminated a sign at the back and front of the housing indicating whether that machine was connected to the power or lighting bus bars.

Feeder switchboard

The feeder switchboard, which functioned as the main distribution panel to route electricity to all areas of the ship, was located in the switchboard gallery at the Orlop Deck level above the forward end of the Electric Engine Room. From the main dynamo switchgear, the current passed by insulated cables below the switchboard gallery to the feeder switchboard; like the main switch gear, this was constructed by Dorman & Smith. The main feeder switchboard was located at the forward end of the gallery, near the watertight bulkhead separating the compartment from the Turbine Engine Room. It ran athwartships across nearly the full width of the compartment and faced aft. The switchboard consisted of twenty-five panels equipped with gear for controlling two circuits on each panel, making fifty circuits in all, each of 600 amps capacity.

Each of the twenty-five panels was manufactured of black polished slate, upon which was mounted the fuses and automatic cutouts for the two circuits that shared the panel. Each panel had a pilot light bracket and each circuit had a moving coil ammeter. Each circuit was controlled by a breaker and a large, main handle-type fuse. Each of the circuit breakers was capable of being operated by hand release or by a Ferranti overload control with inverse time element breakers. Inverse time element breakers, invented in 1904, were constructed with a clockwork mechanism that delayed the tripping of the breaker until a predetermined interval of time passed. This permitted the fuse controlling the local circuit elsewhere in the ship to trip first, thereby preventing interruption to an entire branch circuit. They were termed 'inverse time element' breakers because the lower the overload, the greater the time that would elapse before the timer operated to open the circuit.

In designing the circuit breakers, careful attention was given to the question of reliability. Every possible detail such as the throw-out springs, trigger springs, cushion springs, auxiliary metallic and carbon breaks, etc., had been arranged in duplicate, so that the breakage of any one part would not affect the working efficiency of the breaker.

The main dynamo cable connections from the main selector switches were connected to the bus bars through massive copper connectors bolted up with steel clamps, and the connection surfaces were spread along the central part of the bus bar so that the current density was kept low. The main bus bars for the power circuits were of 8.4sq.in section, while those for the lighting circuits were of 3sq.in section. The latter ran the full length of the board, the power circuits being arranged on the center panels and the lighting circuits in two parts – at the port and starboard ends, respectively.

Branch circuits

From the feeder switchboard forty-eight cables ran to master fuse boxes throughout the ship. These exited from the feeder board, passing vertically up two rectangular steel trunks (one each port and starboard), each 7ft by 3ft with a central ventilation passage between them.[7] They ranged in sectional area up to 61/12 SWG[8] and terminated in master fuse boxes on each deck from which ran the individual circuit cables. These ran along the main passages of the different decks throughout the vessel from where they branched out to the distribution

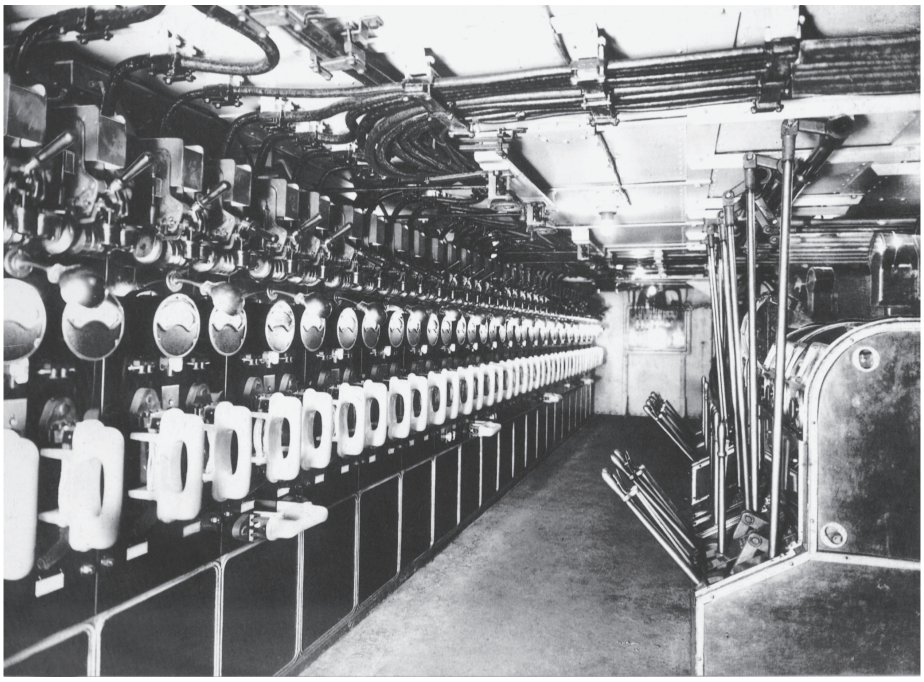


Fig. 17-15 **Main Switches and Feeder Switchboard** – Main switches and feeder switchboard as fitted on *Olympic*. *(*The Electrician*/ Authors' collection)*

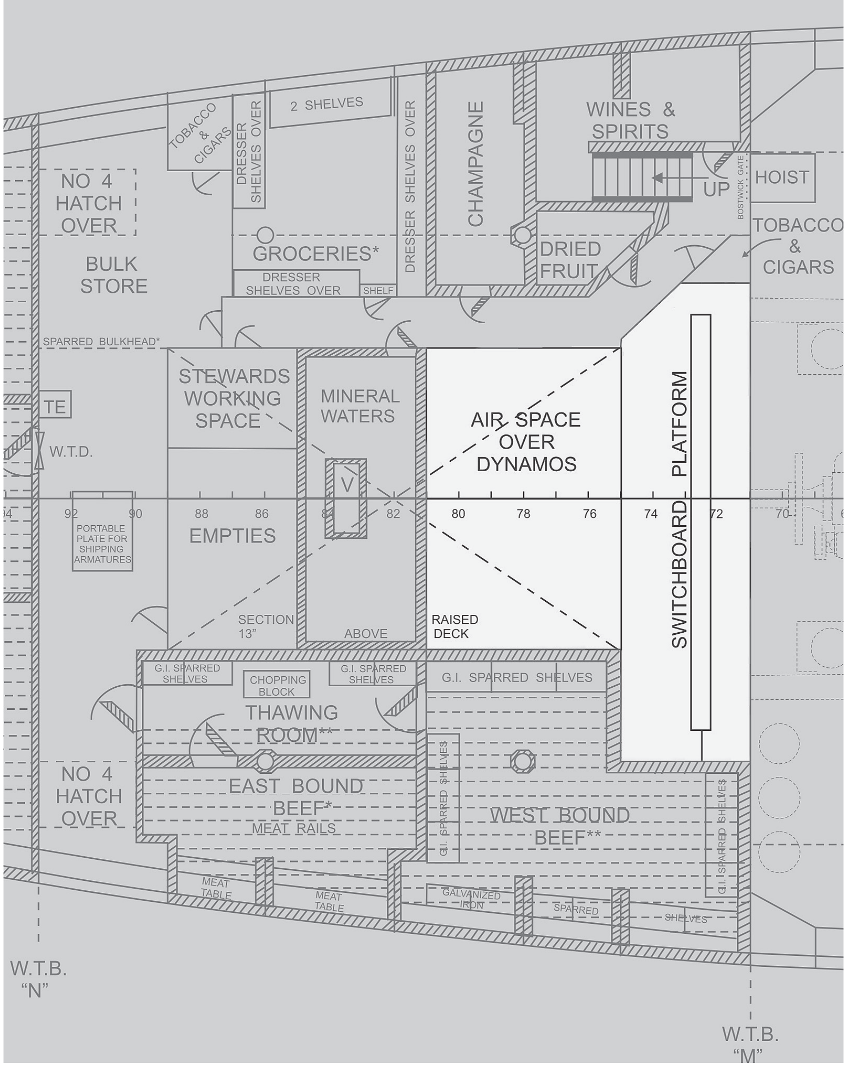
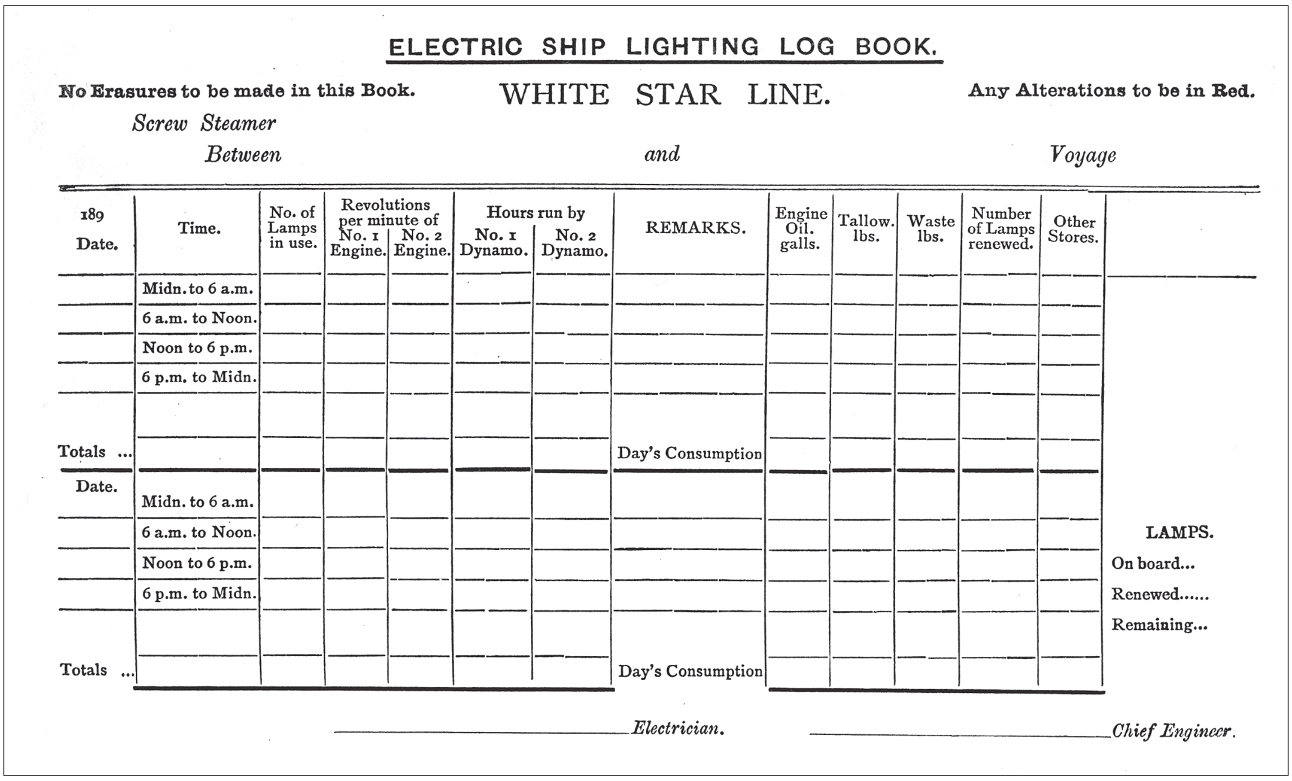

TOBACCO & CIGARS
DRESSER SHELVES OVER
2 SHELVES
DRESSER SHELVES OVER
CHAMPAGNE
WINES & SPIRITS
UP
BOSTWICK GATE
HOIST
NO 4 HATCH OVER
BULK STORE
GROCERIES*
DRESSER SHELVES OVER
SHELF
DRIED FRUIT
TOBACCO & CIGARS
SPARRED BULKHEAD*
TE
W.T.D.
STEWARDS WORKING SPACE
MINERAL WATERS
V
AIR SPACE OVER DYNAMOS
SWITCHBOARD PLATFORM
94
92
90
88
86
84
82
80
78
76
74
72
70
PORTABLE PLATE FOR SHIPPING ARMATURES
EMPTIES
SECTION 13"
ABOVE
RAISED DECK
G.I. SPARRED SHELVES
CHOPPING BLOCK
G.I. SPARRED SHELVES
G.I. SPARRED SHELVES
THAWING ROOM**
NO 4 HATCH OVER
EAST BOUND BEEF*
MEAT RAILS
G.I. SPARRED SHELVES
WEST BOUND BEEF**
G.I. SPARRED SHELVES
MEAT TABLE
MEAT TABLE
GALVANIZED IRON
SPARRED
SHELVES
W.T.B. "N"
W.T.B. "M"

Fig. 17-16 **Plan of Switchboard Platform** – This detail from the general arrangement plan shows the location of the switchboard platform on the Orlop Deck. Above this area were two ventilation trunks which doubled as conduits for the port and starboard electrical mains. These two trunks terminated at the aft end of the Boat Deck abeam of the Second Class Entrance. *(Illustration by Bruce Beveridge)*



ELECTRIC SHIP LIGHTING LOG BOOK.

No Erasures to be made in this Book. WHITE STAR LINE. **Any Alterations to be in Red.**

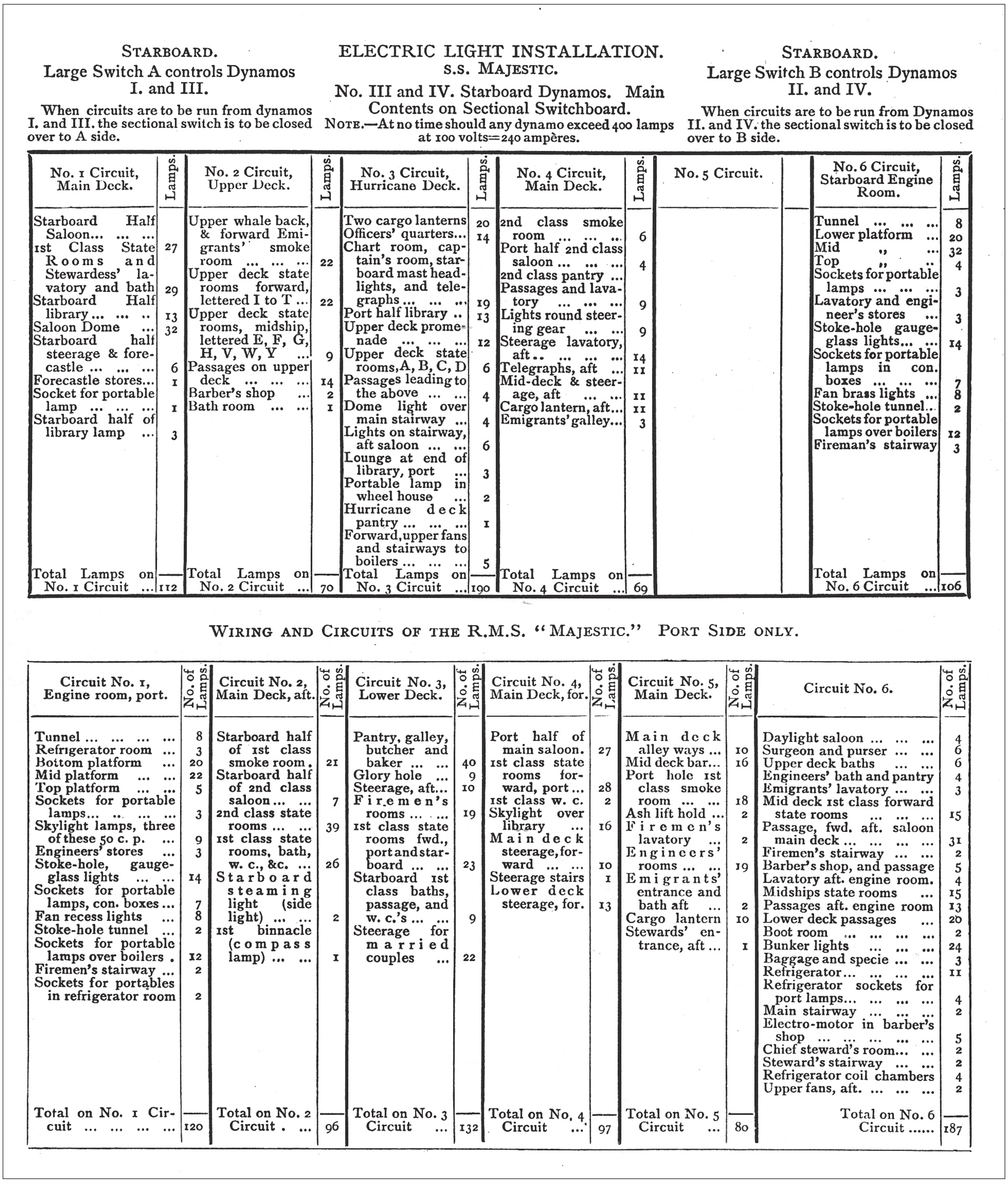
Screw Steamer

Between *and* *Voyage*

189 Date.	Time.	No. of Lamps in use.	Revolutions per minute of No. 1 Engine.	Revolutions per minute of No. 2 Engine.	Hours run by No. 1 Dynamo.	Hours run by No. 2 Dynamo.	REMARKS.	Engine Oil. galls.	Tallow. lbs.	Waste lbs.	Number of Lamps renewed.	Other Stores.	
	Midn. to 6 a.m.												
	6 a.m. to Noon.												
	Noon to 6 p.m.												
	6 p.m. to Midn.												
Totals ...							Day's Consumption						
Date.	Midn. to 6 a.m.												
	6 a.m. to Noon.												**LAMPS.**
	Noon to 6 p.m.												On board...
	6 p.m. to Midn.												Renewed......
													Remaining...
Totals ...							Day's Consumption						

_____________ *Electrician.* _____________ *Chief Engineer.*

Fig. 17-17 **Electrician's Log** – A blank form copy of a White Star Line Electrician's log from the late 1800s.



STARBOARD.
Large Switch A controls Dynamos I. and III.

When circuits are to be run from dynamos I. and III. the sectional switch is to be closed over to A side.

ELECTRIC LIGHT INSTALLATION.
S.S. MAJESTIC.
No. III and IV. Starboard Dynamos. Main Contents on Sectional Switchboard.
NOTE.—At no time should any dynamo exceed 400 lamps at 100 volts=240 ampères.

STARBOARD.
Large Switch B controls Dynamos II. and IV.

When circuits are to be run from Dynamos II. and IV. the sectional switch is to be closed over to B side.

No. 1 Circuit, Main Deck.	Lamps.
Starboard Half Saloon...	27
1st Class State Rooms and Stewardess' lavatory and bath	29
Starboard Half library...	13
Saloon Dome ...	32
Starboard half steerage & forecastle	6
Forecastle stores...	1
Socket for portable lamp	1
Starboard half of library lamp ...	3
Total Lamps on No. 1 Circuit ...	112

No. 2 Circuit, Upper Deck.	Lamps.
Upper whale back, & forward Emigrants' smoke room	22
Upper deck state rooms forward, lettered I to T ...	22
Upper deck state rooms, midship, lettered E, F, G, H, V, W, Y ...	9
Passages on upper deck	14
Barber's shop ...	2
Bath room	1
Total Lamps on No. 2 Circuit ...	70

No. 3 Circuit, Hurricane Deck.	Lamps.
Two cargo lanterns	20
Officers' quarters...	14
Chart room, captain's room, starboard mast headlights, and telegraphs	19
Port half library ..	13
Upper deck promenade	12
Upper deck state rooms, A, B, C, D	6
Passages leading to the above	4
Dome light over main stairway ...	4
Lights on stairway, aft saloon	6
Lounge at end of library, port ...	3
Portable lamp in wheel house ...	2
Hurricane deck pantry	1
Forward, upper fans and stairways to boilers	5
Total Lamps on No. 3 Circuit ...	190

No. 4 Circuit, Main Deck.	Lamps.
2nd class smoke room	6
Port half 2nd class saloon	4
2nd class pantry ...	
Passages and lavatory	9
Lights round steering gear	9
Steerage lavatory, aft..	14
Telegraphs, aft ...	11
Mid-deck & steerage, aft	11
Cargo lantern, aft...	11
Emigrants' galley...	3
Total Lamps on No. 4 Circuit ...	69

No. 5 Circuit.	

No. 6 Circuit, Starboard Engine Room.	Lamps.
Tunnel	8
Lower platform ...	20
Mid " ...	32
Top " ..	4
Sockets for portable lamps	3
Lavatory and engineer's stores ...	3
Stoke-hole gauge-glass lights... ...	14
Sockets for portable lamps in con. boxes	7
Fan brass lights ...	8
Stoke-hole tunnel..	2
Sockets for portable lamps over boilers	12
Fireman's stairway	3
Total Lamps on No. 6 Circuit ...	106

WIRING AND CIRCUITS OF THE R.M.S. "MAJESTIC." PORT SIDE ONLY.

Circuit No. 1, Engine room, port.	No. of Lamps.
Tunnel	8
Refrigerator room ...	3
Bottom platform ...	20
Mid platform	22
Top platform	5
Sockets for portable lamps...	3
Skylight lamps, three of these 50 c. p. ...	9
Engineers' stores ...	3
Stoke-hole, gauge-glass lights	14
Sockets for portable lamps, con. boxes...	7
Fan recess lights ...	8
Stoke-hole tunnel ...	2
Sockets for portable lamps over boilers .	12
Firemen's stairway ...	2
Sockets for portables in refrigerator room	2
Total on No. 1 Circuit	120

Circuit No. 2, Main Deck, aft.	No. of Lamps.
Starboard half of 1st class smoke room .	21
Starboard half of 2nd class saloon... ...	7
2nd class state rooms	39
1st class state rooms, bath, w. c., &c. ...	26
Starboard steaming light (side light)	2
1st binnacle (compass lamp)	1
Total on No. 2 Circuit	96

Circuit No. 3, Lower Deck.	No. of Lamps.
Pantry, galley, butcher and baker	40
Glory hole ...	9
Steerage, aft...	10
Firemen's rooms	19
1st class state rooms fwd., port and starboard	23
Starboard 1st class baths, passage, and w. c.'s	9
Steerage for married couples ...	22
Total on No. 3 Circuit ...	132

Circuit No. 4, Main Deck, for.	No. of Lamps.
Port half of main saloon.	27
1st class state rooms forward, port...	28
1st class w. c.	2
Skylight over library ...	16
Main deck steerage, forward	10
Steerage stairs	1
Lower deck steerage, for.	13
Total on No. 4 Circuit ...	97

Circuit No. 5, Main Deck.	No. of Lamps.
Main deck alley ways ...	10
Mid deck bar...	16
Port hole 1st class smoke room	18
Ash lift hold ...	2
Firemen's lavatory ...	2
Engineers' rooms	19
Emigrants' entrance and bath aft ...	2
Cargo lantern	10
Stewards' entrance, aft ...	1
Total on No. 5 Circuit ...	80

Circuit No. 6.	No. of Lamps.
Daylight saloon	4
Surgeon and purser	6
Upper deck baths	6
Engineers' bath and pantry	4
Emigrants' lavatory	3
Mid deck 1st class forward state rooms	15
Passage, fwd. aft. saloon main deck	31
Firemen's stairway	2
Barber's shop, and passage	5
Lavatory aft. engine room.	4
Midships state rooms ...	15
Passages aft. engine room	13
Lower deck passages ...	20
Boot room	2
Bunker lights	24
Baggage and specie	3
Refrigerator...	11
Refrigerator sockets for port lamps...	4
Main stairway	2
Electro-motor in barber's shop	5
Chief steward's room... ...	2
Steward's stairway	2
Refrigerator coil chambers	4
Upper fans, aft.	2
Total on No. 6 Circuit	187

Fig. 17-18 **Light Installation on *Majestic*** – A very rare list of the electric light installation on the White Star Line's first *Majestic* (Harland & Wolff Yard No.209), delivered in 1890.

boxes. From these distribution boxes ran the individual cables supplying current to the lights, motors, heaters and other devices.

The power and heating supply could be run independent of the lighting supply as there were power and light bus-bars on the switchboard which could be paralleled or separated as needed. The circuits were further split so that the passenger accommodations, public areas, crew, cargo, machinery spaces and individual motors (or groups of motors) were independent and could be switched on or off to suit specific conditions. Local switches were provided for turning off individual lights or machines. Common practice was to fit one switch for each fuse on each distribution board, with each switch controlling about four lights. A switch was also fitted beside each hand lamp plug. The lights in the individual shops and store rooms had their own separate switches. It is impossible to give a definite figure for the number of lights required owing to the variation in the sizes and shape of the machinery spaces and ancillary compartments on *Titanic*, but on average, sufficient illumination could be obtained by arranging the lamps not less than 8ft apart.

The practice of shipbuilders was to divide the ship into sections or circuits; a switch and fuse was fitted on the main board for each one. Following are detailed descriptions of the various circuits throughout the ship.

(1) The Machinery Space Circuit

The main cables were run from the main switchboard to a fuse board fitted with numerous fuses, each having an average capacity of 15 to 20 amps each. This fuse board, in turn, fed distribution boards located throughout the machinery spaces. These distribution boards were fitted in the following positions:

Boiler Rooms:

Distribution Boards were fitted in the boiler rooms to supply the following: the lamps fitted along the firing aisles and in the passages between boilers from one firing aisle to another; lamps for illuminating the water and steam gauges; the lamps above the catwalks which ran above the boilers; lights in fan rooms and in the entrances to boiler rooms from the fidley trunks; the portable lights, single hand-lamps and three-light clusters for use in the coal bunkers. These last-named were taken off plug-and-socket connections fitted beside the bunker doors.

Engine Rooms:

One distribution board was located in the forward end of each engine room, and supplied about half of the engine room lights. These included lights near the forward bulkhead over the pumps, also some near the main engines and on the starting platform as well as some in the side wings. A second distribution board was located in the after end of each engine room and supplied the remainder of the lights beside the main engines and the remainder of those in the side wings. From either of these distribution boards, individual lights over all of the main and thrust bearings were supplied.

Shaft Tunnels:

From either of the after distribution boards in the Turbine Engine Room, or from one like it at the after end of the Electric Engine Room, power would have been supplied to the lights in the shaft tunnels. There would have been at least one light over each bearing and two or more in the recess at the end of each tunnel. Beside the fixed lights already mentioned, a number of portable hand-lamps were always provided for through plug-and-socket connections in the engine and tunnel spaces, with a minimum of two at the forward end and two at the after end of each engine room.

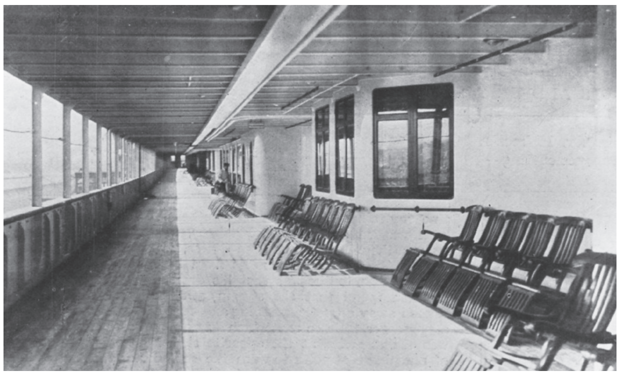


Fig. 17-19 **Promenade Deck** – The A Deck promenade on *Titanic*'s port side. Though it is not confirmed, the authors believe the navigational wiring to the Bridge was run within the box-like shroud running along the deckhead in this photo.

(2) The Navigating Light Circuit

This very important circuit was nearly always used exclusively for those lights that were required by Board of Trade regulations to be in operation when the vessel was underway: the forward masthead light and the port and starboard sidelights.[9] Also included on this circuit were the lights for engine and docking telegraphs, steering and standard compasses, and Morse lamps.

The main cables ran without interruption from the main switchboard to the Chart Room where the only fuse board on this circuit was fitted. The run was a long and rather difficult one due to the number of decks through which the mains had to pass and the fact that the Chart Room was situated over First Class staterooms. Shipbuilders often found it difficult to find a suitable run for the cables which would be clear of the paneling. One method of avoiding this difficulty was to run the navigating light mains in tubing or trunks outside the deckhouses. The advantage with this method was that the cables were always accessible without having to dismantle the panels in any of the rooms.

The fuse board for this circuit was arranged to provide each navigation light with its own fuse and its own switch; this necessitated a separate pair of wires to each of the sidelights. The telegraphs and compasses, however, were looped in pairs on one fuse. Because of the close

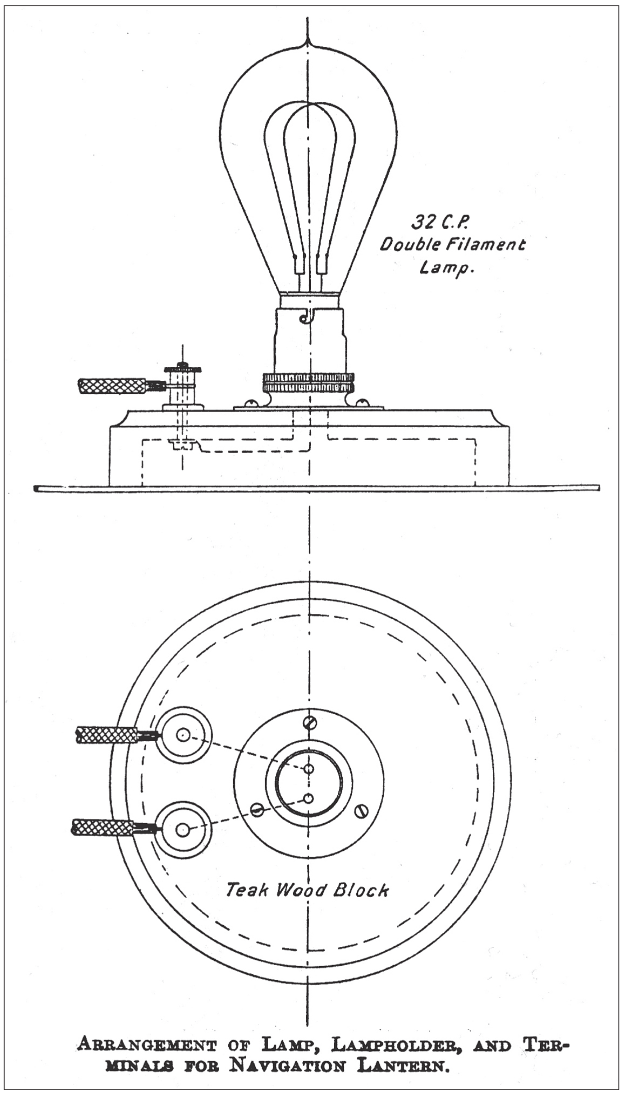

32 C.P.
Double Filament
Lamp.
Teak Wood Block
ARRANGEMENT OF LAMP, LAMPHOLDER, AND TERMINALS FOR NAVIGATION LANTERN.

Fig. 17-20 **Light Bulb Holder for Navigational Lamp**.

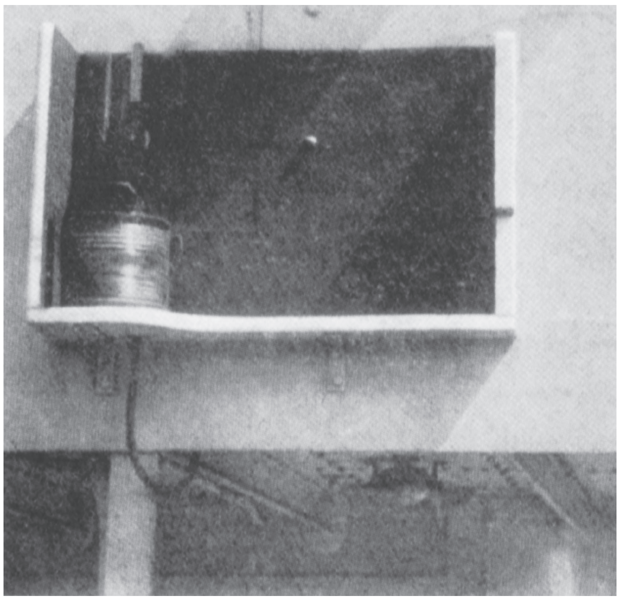


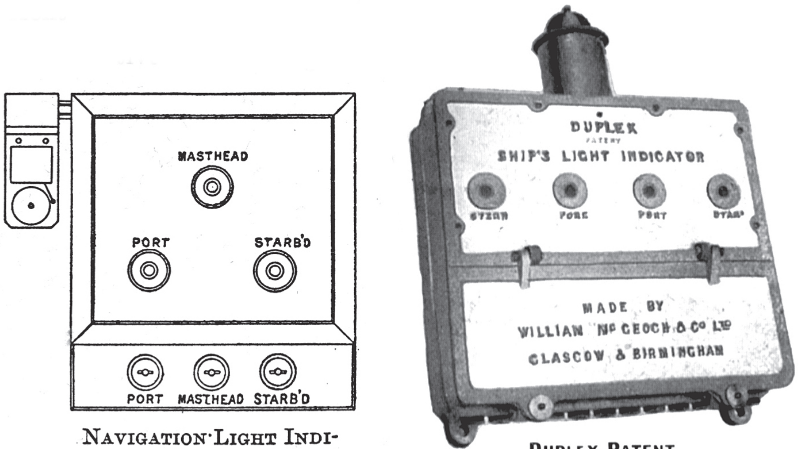
Fig. 17-21 **Sidelight on *Titanic*'s Starboard Side** – In this detail from a photograph of *Olympic*'s starboard Bridge wing cab, the starboard sidelight is shown in good detail.

proximity of this wiring to the compasses, the Board of Trade required all wires within a radius of 15ft around the compasses to be doubled, with the positive and negative wires run together in twisted pairs to prevent them from having any electromagnetic effect on the compass needles. By doing this, any magnetic field produced by the positive wire was neutralized by wrapping it with the negative.

The light bulbs used in the forward masthead, stern and sidelights were specially constructed by W.H. Allen & Co. of Bedford. They were of 32 candlepower collectively, having two filaments of 16 candlepower, each suitable for the working voltage and connected in parallel. If one filament gave out the other would remain burning. The illumination would, however, be only 16 candlepower until the partially burned-out bulb was replaced. The main for the masthead light ran up the mast internally in a galvanized iron pipe of about ¾in bore. The pipe was secured to the inside of the mast by means of galvanized iron clips spaced about 3ft apart. From the internal pipe, the wires exited the mast through a hole and entered the lighting assembly through a hole in the rear. The assembly was attached to the mast by means of two posts mounted on the face of the mast at an angle to position the lights parallel to the waterline.

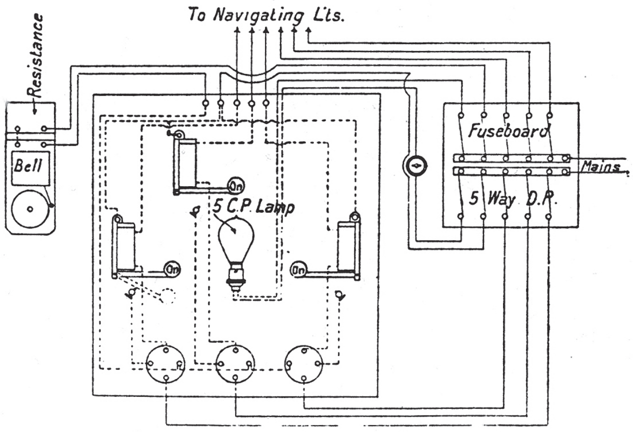
The two sidelights were located one on either side at the extreme sides of the bridge wings. The starboard light had a green glass lens; the port light a red glass lens. The interior of these lights consisted of a round hardwood block with a flanged lamp-holder mounted in the center. There were two terminals on the block connected to the bulb holder. The feed wires were brought into the sidelights and connected to the terminals by passing the wires up through the under side of the assemblies from tubing beneath. Great care was necessary to see that the bulb was positioned properly, as the lens' ability to project the light over a great distance depended on the filament of the bulb being positioned exactly in the center of the dioptric plane of the lens. A run was provided for these wires under the bridge in galvanized iron piping.

The compasses and telegraphs were wired from underneath. The telegraphs were each fitted with a lamp inside (behind the dials) with an external switch located on the pedestal. For binnacles there were a number of methods of fitting an electric light depending on the type of compass. One type had the light fitted inside in a manner similar to the telegraphs; in that case, the wires were brought up inside. Another method was adopted for compasses having a recess at each side, one of which was for an electric lamp. In this type the lamp was made portable so that it could be removed in the event of failure and an oil lamp substituted. There was also a design that incorporated both methods of lighting. The



Navigation·Light Indicator—General View.

Duplex Patent
SHIP'S LIGHT INDICATOR.
As supplied to Q.T.S.S. "LUSITANIA."



Navigation Light Indicator—Internal and External Connexions.

Fig. 17-22 **Navigational Lamp Indicator** – At upper left, a drawing of a basic navigational lamp indicator; bottom, a schematic diagram of the same indicator. At upper right, an example of one fitted to *Lusitania*. This device was a common shipboard instrument, and the McGeoch company provided a lot of fittings for Harland & Wolff, but evidence has yet to surface as to who manufactured *Titanic*'s. The reader will notice the drawing shows only three lamps – fore, port and starboard. The *Lusitania*'s shows a fourth lamp titled 'stern.' This is more than likely indicating an electric navigation lamp that was fitted to the mainmast. An electric running light on the mainmast was not compulsory in 1912 but optional under the Rules of the Road. *Titanic*'s after masthead light, if one was present, was almost certainly an oil lamp hoisted up a stay.

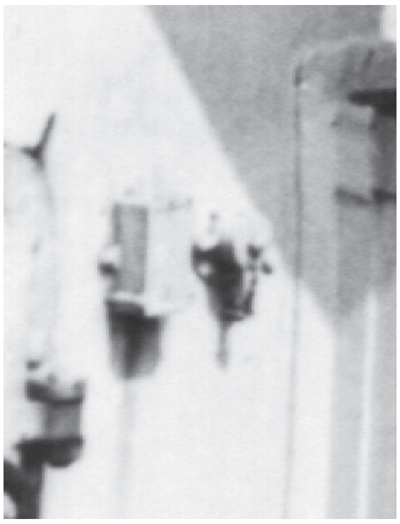


Fig. 17-23 **Exterior Outlets** – Two exterior outlets used for supplying power to arc lamps and cluster lights on *Olympic*.

lamp was connected by means of a short flexible lead to a plug and socket fitted about halfway down the pedestal. The telegraph and compass lights did not need to be on separate fuses; two of each, for example, could be taken off one fuse.

To avoid failure of any of the navigating lights without some warning being given to the officer on watch, an apparatus called a 'navigating light indicator' rang a bell as soon as any of the lights failed. The indicator was arranged with three lights: the foremast head, the port sidelight and the starboard sidelight.

The working of the indicator was simple. Each movement consisted of an electromagnet with an armature and disc. The circuit of each bulb passed around its respective electromagnet which, when the light was switched on, attracted the armature and raised the disc to the position which indicated light 'ON'. If the bulb burned out or the circuit was broken, the lack of current from the burned-out bulb circuit would release an armature, which would fall onto a contact activating that specific light circuit's electromagnet, thereby activating the bell. The bell would continue to ring until the fault was corrected. The bell worked off the supply mains with a suitable resistance in circuit. The specialized switches had four contacts: two for the lamp circuit and two for the bell. The latter was broken when the switch was turned off, with the bell thus stopped from ringing while the repairs were being carried out. The dial of the indicator was illuminated by means of a 5-candlepower lamp inside the case; this showed through the indicator hole the moment the disc dropped. The fuse board was of the double-pole type as the wiring for the indicator was near the compasses located in the Chart Room.

(3) The Cargo Light Circuit

This circuit, as its name implies, was the one which carried the lights in the holds and the portable arc lights for deck use when the ship was in port and the work of loading and unloading cargo was in progress.

Fixed lights were rarely fitted in the holds as electric cables of all kinds were kept out of the holds wherever possible. When cables were unavoidably passed through the holds, they were run in galvanized iron gas pipe, with the best possible mechanical protection given to them, so as to minimize the risks of fire through short circuit or by mechanical damage which might result in an unintentionally grounded circuit. Pipes were run alongside the beams wherever possible or in some sheltered place out of the way of the cargo.

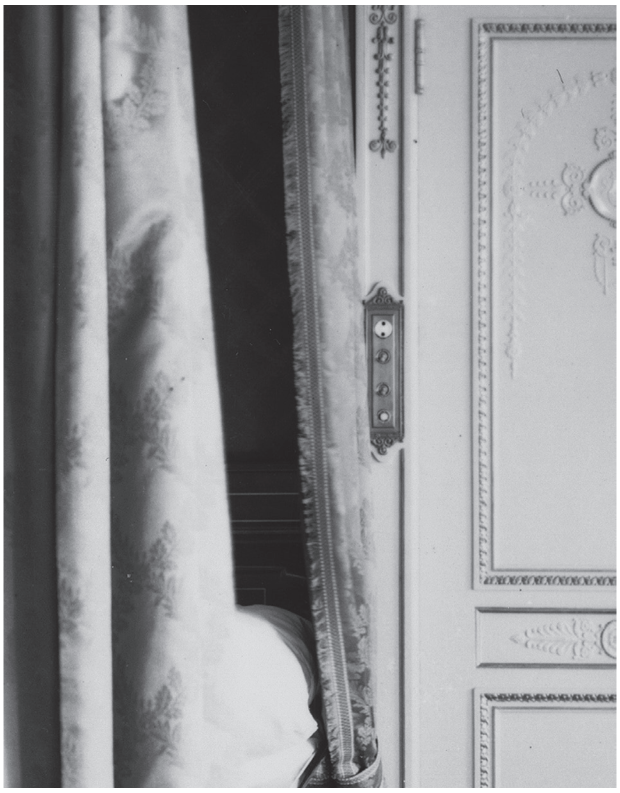


Fig. 17-24 **Stateroom Light Switch and Call Panel** – A light switch, Steward call panel and electric outlet positioned next to a bed in one of *Titanic*'s period staterooms. *(H&W/Daniel Klistorner collection)*

The distribution fuse boards and switches for these lights were situated on a deck above the hold space.

(4) and (5) The Port and Starboard Saloon Circuits

These two circuits were similar, one handling the port side of the ship and the other the starboard side. As with the other circuits, the mains were run from the main board in the Electric Engine Room through steel trunks, one on each side of the ship. The mains then connected to master fuse boxes on each deck. The electrical supply for each deck ran along the passageways, terminating in distribution boxes located in convenient areas. In the First and Second Class areas of the ship, care was taken to conceal these boxes behind hinged decorative panels or by other means wherever located within public areas. The position of the main fuse boxes was central to all the distribution boxes on the deck. It was not at all uncommon on many large liners to fit the fuse box beside a distribution box on the run, i.e., beside the boxes nearest to the Electric Engine Room on the main run. Other leads were taken from the fuse box to the various other distribution boxes on the circuit. The public rooms (such as the Dining Saloon, Smoke Room, etc.) belonging to the First Class accommodations would be on this circuit. The switches for the lights in these rooms were fitted in the pantries or other places accessible to the Stewards.

Beside the rooms mentioned above, separate and distinct distribution boxes were allocated to the lighting in the staterooms, lavatories, bathrooms, corridors, pantries and entrances. Each ordinary stateroom had at least one pendant light in the center of the room or over the mirror; the switch for this light was fixed in the most

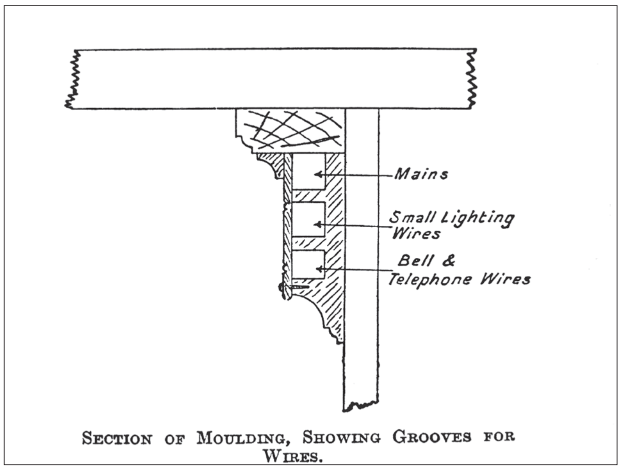


Fig. 17-25 **Routing of Wires Through Joinery** – This cross-sectional drawing showing a typical routing of wires behind decorative molding.

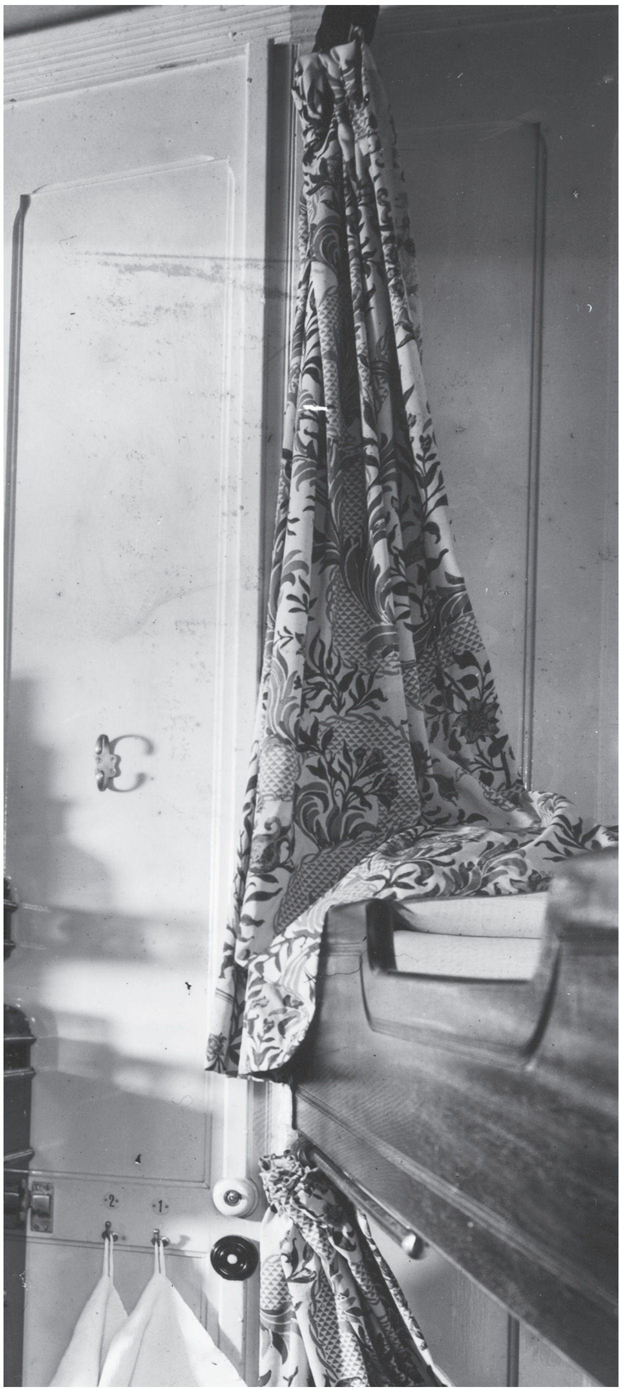


Fig. 17-26 **Concealed Wiring Behind Casing** – The wiring in this Second Class stateroom has been concealed under a casing mounted to the bulkhead paneling. *(Daniel Klistorner collection)*

convenient position for the passengers to reach from the berths.

Some of the smaller, ordinary First Class staterooms were fitted with one ceiling light, the larger staterooms having two or three. The 'special staterooms' decorated in period styles had one ceiling fitting (which no doubt was fitted with three light bulbs) and were always accompanied by a number of wall appliqués.

The other large suites were fitted with four single-bulb ceiling lights. Usually there were a number of wall switches for the lights in all First Class staterooms, normally one at the entrance (i.e., at the door when one entered the stateroom) plus additional switches with an electric socket and call button at the head of each bed. There were additional switches and sockets if a light above the dressing table was present, but this was reserved for the better and larger staterooms. The electrical system was simpler for Second and Third Class staterooms and cabins.

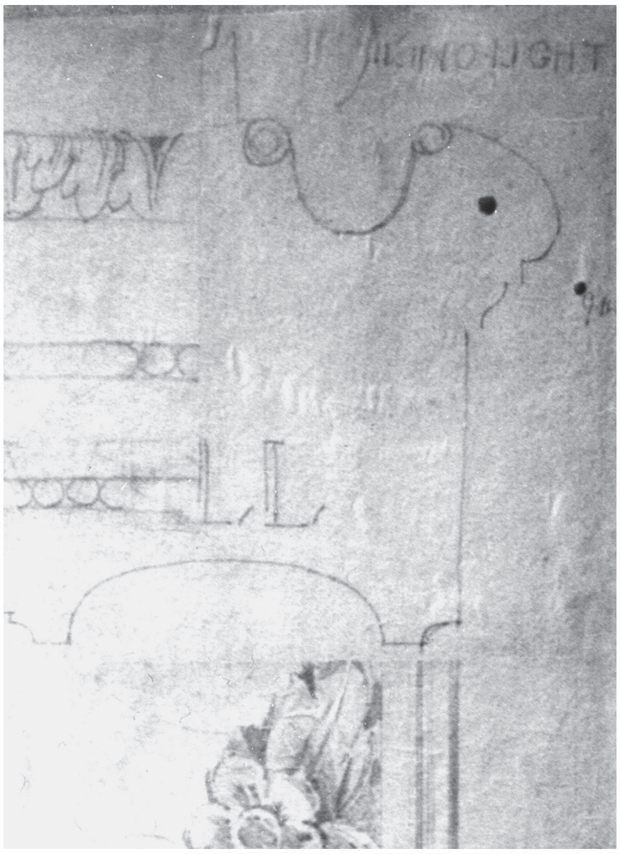
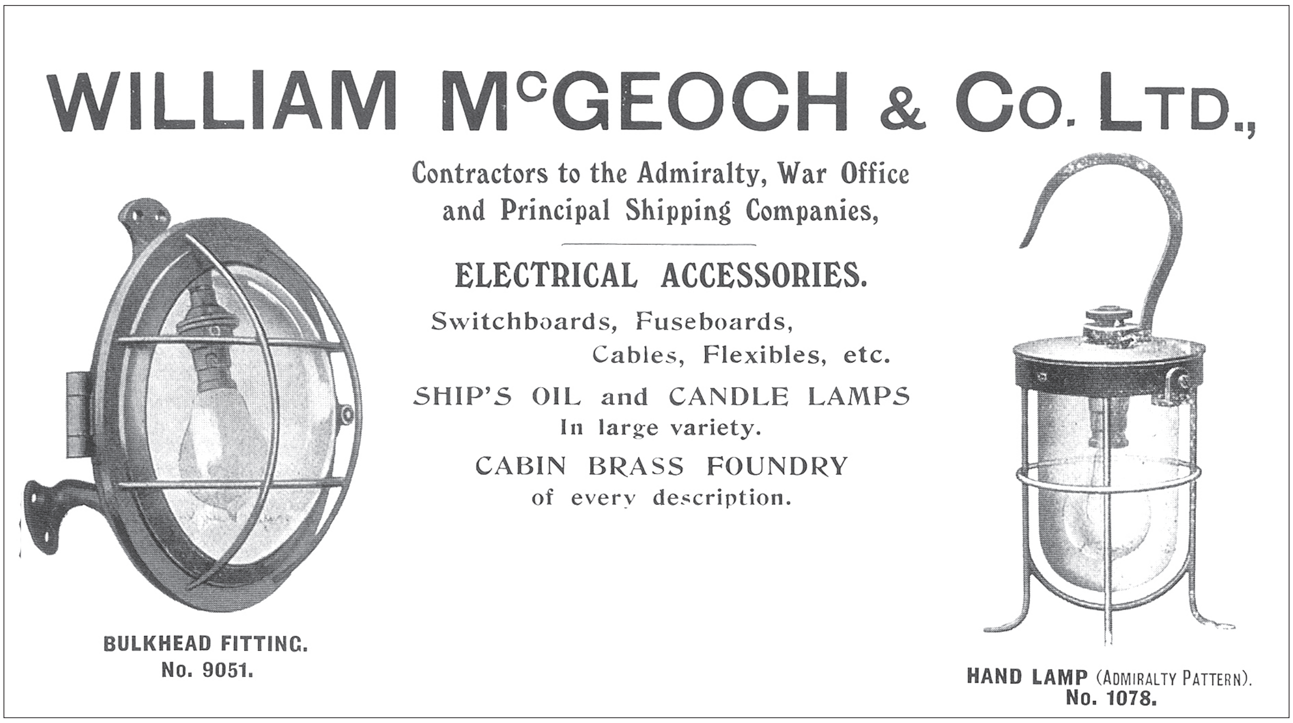


Fig. 17-27 **Linolite Illumination of Skylight Dome** – This original architectural drawing shows a section through the decorative base molding of the staircase dome, indicating where the 'Linolite' was installed. *Titanic*'s domes were not artificially illuminated from outside of the glass, but from within. *(Peter Speakman collection)*

The corridors were generally illuminated by pendant lights spaced about 9ft apart. The main fore-and-aft passageways on B and C Decks had 7½in ceiling fixtures at this spacing, while the other corridors in First Class had porcelain ceiling lights spaced about every 4 frames, or about every 12ft. In Second Class the lights in the main corridors were may also have been spaced 12ft apart, but generally were slightly more widely spaced. The lights along the working crew passageway on E Deck were mounted to the wall rather then the deckhead, owing to the maze of pipes and ducting overhead. A switch for every pendant light, located beneath it, was a general shipboard practice but may not have been utilized in all instances on *Titanic*. It was common to fit master switches at the fuse boxes, one for each distribution box, so that a section



WILLIAM McGEOCH & Co. Ltd.,

Contractors to the Admiralty, War Office
and Principal Shipping Companies,

ELECTRICAL ACCESSORIES.

Switchboards, Fuseboards,
Cables, Flexibles, etc.

SHIP'S OIL and CANDLE LAMPS
In large variety.

CABIN BRASS FOUNDRY
of every description.

BULKHEAD FITTINC.
No. 9051.

HAND LAMP (Admiralty Pattern).
No. 1078.

Fig. 17-28 **William McGeoch & Co. Advertisement** – The William McGeoch Company supplied electrical fittings not only for Harland & Wolff, but also for the *Lusitania*. This was printed around the time of the *Lusitania's* emergence; however, deck lights of the design at left were seen on *Titanic* also. In the sample illustrated here, the light has protective guards over the glass. The deck lights mounted to the forward-facing C Deck bulkhead in the forward Well Deck would be fitted in the same manner, but those on the promenades were not. The McGeoch company also supplied lamps, door hooks, and other marine hardware, and in fact the Scottish contractor's logo has been found on the light bulb sockets of some of the fittings from the *Nomadic*, one of the White Star Line's tenders at Cherbourg (still in existence as of this writing). *(*The Shipbuilder*/Authors' collection)*

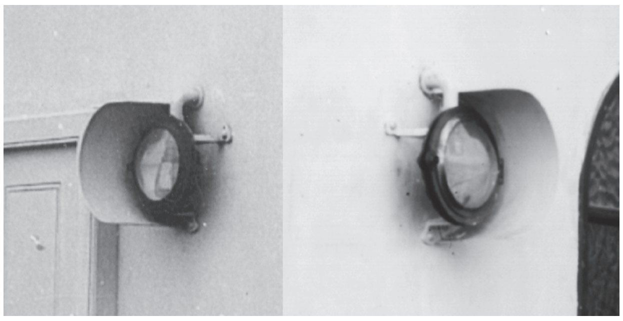


Fig. 17-29 **Deck Lights on *Olympic*** – These enlarged photograph details show two of *Olympic*'s deck lights. Notice the brass frame around the glass, with the innermost ring being polished. Measuring about 9¼in in diameter and 4½in thick, the lights shown here were also fitted with shrouds on their forward sides to eliminate glare toward the Bridge.

of lights (usually twenty to thirty) could be switched off without going to the individual switches. It was required that some lights remain burning in each public room or entrance to serve as night-lights and to remain burning when all the other lights were switched off.

The lights intended for night-light use were on separate switches and fuses and not under the control of the master switches, nor were they connected to the bus-bar of the fuse box. As previously stated, on *Titanic* much of this was provided by lights on the emergency circuit.

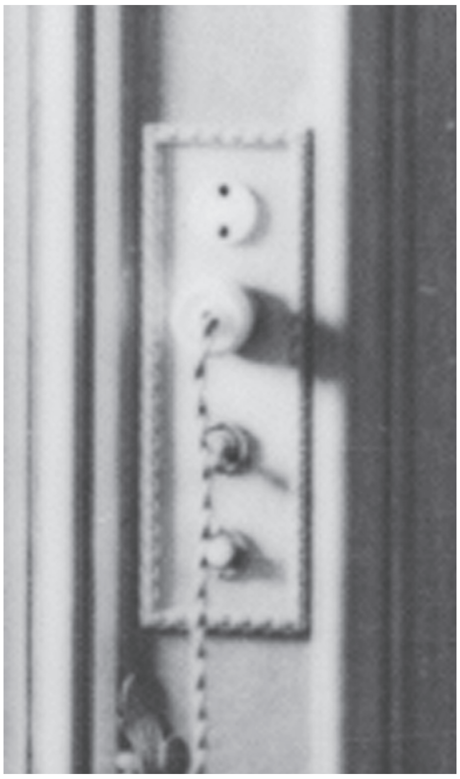


Fig. 17-30 **Electrical Wiring in Stateroom** – A stateroom panel with electric sockets for ancillary devices such as portable lamps, fans, etc. On the lower half of the panel is a Steward call button and a glow-lamp switch. *(Daniel Klistorner collection)*

In corridors, cable runs were under moldings for the most part, and casings were only used when stepping out to a light or switch. The back of the molding was hollowed and had two or three grooves: one for main lighting cables; one for the small lighting cables; and another for the bell, telephone, and other similar wires. In staterooms, a small casing was run to the light and down to the switch. The arrangements in the pantries, lavatories and bathrooms were similar. In the 'special staterooms' decorated in period designs, however, more attention was given to appearance. These rooms were decorated with ornamental panels both on the ceilings and on the bulkheads, and no ordinary casing was used. Wires were run behind moldings, panels, etc.; since these were screwed in place, access could not always be had to the wires.

Main runs were arranged alongside one of the fore-and-aft beams which formed a division between the panels. The lower side of the beam took the form of a fancy capping and was fixed with screws. The small wires stepped out from the main run to the centers of panels where the fittings were placed.

Lights fitted within the skylight domes over the First Class Entrances were intended to illuminate the domes themselves for visual effect, rather than to provide light to the spaces below. However, the domes were fitted with an illuminating light fixture directly in the middle of the wrought-iron framework in addition to a series of specially designed light bulbs which went under the brand name of 'Linolite'. The Linolite bulbs – tubular, incandescent bulbs similar in size and shape to a modern, miniature fluorescent lamp – were fitted within the decorative wooden crown molding which formed the base of the ironwork.

In addition to the interior lighting there were a number of deck lights on this circuit. These included lights fitted on the weather decks. The fittings used for deck lights were of the 'oyster' type, supplied by William McGeoch & Co. Ltd as the Glasgow agents for N. Burt & Co. These lights were fixed to the deck head or on the sides of the deckhouses and railings. They were approximately 9¼in in diameter and spaced approximately 20ft apart.

In addition to fixed lights in the First and Second Class accommodations, plug-and-socket connections were fitted so that a table fan, table lamp or curling tong heaters could be used when desired.

Electric heaters used aboard *Titanic* required a current of 5 to 10 amps; this was much higher than that drawn by any of the above-mentioned fixtures and appliances. Due to the number of electric heaters aboard, they had separate fuse boxes with fuses of 10 to 15 amps capacity each.

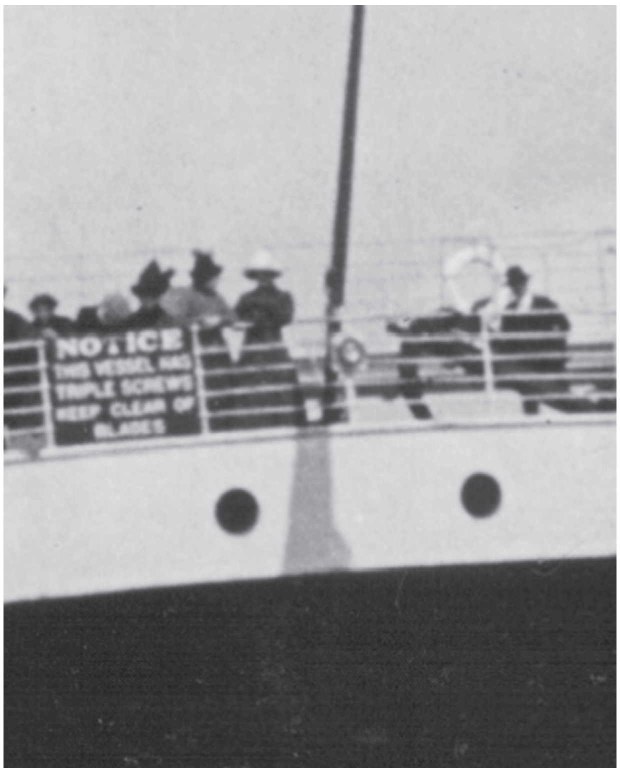


Fig. 17-31 **Stern Light** – *Titanic*'s stern light as seen at Queenstown. It is mounted to the outside of the railing in line with the ensign staff. (Cork Examiner/*Authors' collection*)

(6) The Forward Circuit

As its name implies, this circuit supplied the entire forward section of the ship. This included such areas as the Seamen's, Firemen's, Trimmers' and Greasers' accommodations and messes, the windlass space, the Carpenter's and Bosun's Store, the Chain Lockers, forward stairways and a small number of deck lights. The main supply cables were brought along the main run to a section box at the forward end of an upper deck and secured in a convenient, accessible position. This box had two, three or more ways as required. The sub-mains ran to the distribution boxes, the number of which varied on each deck. The lights were usually looped four on a fuse. Switches in each compartment were fitted beside the lights or just inside the doors.

(7) The Midship Circuit

This circuit supplied the lights in the central portion of the ship below or immediately abaft the part occupied by the passenger accommodation. This included the Galleys, the Butcher's, Baker's and similar shops, the Engineers' accommodations and Mess Room, the Stewards' store rooms, deck and passageway lights, and many other such areas.

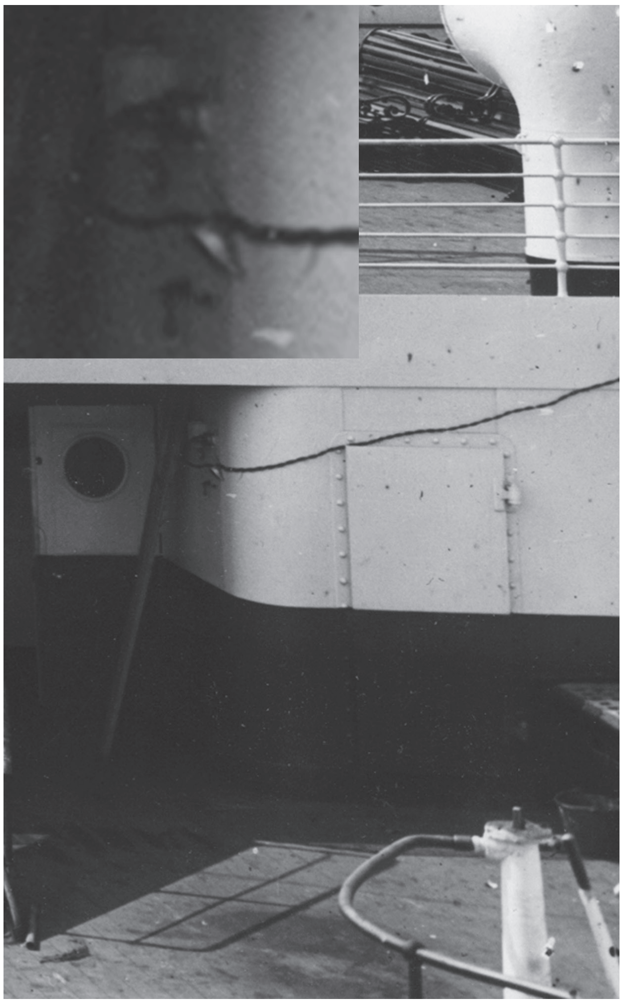


Fig. 17-32 Cargo Cluster Light Plugged In – In this photograph, a cargo cluster light with a double-wire cord is plugged into one of Olympic's exterior electrical boxes. The inset is enlarged to show the socket with its watertight screw cover hanging by a small chain.

The arrangement of wiring and boxes were similar to that of the forward circuit so far as the lights were concerned, but ways were fitted in the distribution boxes for a number of low-power motors and for driving such culinary equipment as mixers, egg-boilers and electric grills.

(8) The After Circuit

This supplied current to lights, etc., at the after portion of the ship, including, but not limited to, the Second and Third Class passenger accommodations; rooms set apart for the use of Stewards, Stewardesses and others; lights in the steering engine space and lights in the instruments on the Docking Bridge. The general arrangement of the main and sub-cables and fuse-boards in this circuit was similar to those of the Forward and Midships circuits. The stern light was also fed from the after circuit, and had a local switch instead of being taken off the Navigating Circuit at the Chart Room fuse box as described in the that section. This may seem strange given that all other such lights were wired on the Navigation circuit, but in 1912 an electric stern light was not mandatory under navigational regulations and therefore was not considered by the Board of Trade to be a part of the ship's compliment of steaming lights.

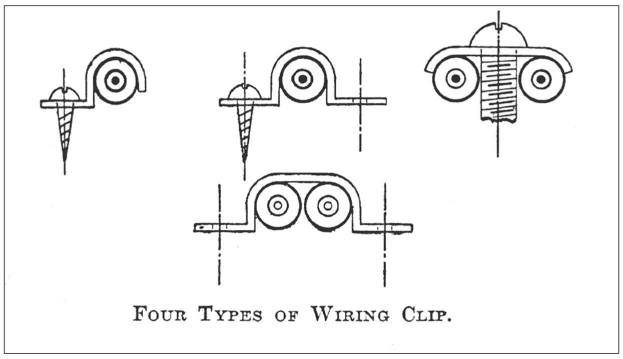


Fig. 17-33 **Various Styles of Wiring Clips**.

(9) The General Motor Circuit

This circuit was only required in medium-to-large ships and supplied all motors required for driving large ventilating fans, galley machines, passenger and goods hoists, pumps, turning gear for the turbine engine and other machines connected with the engine room.

The number of fuse boxes on the circuit depended on the number, disposition and sizes of the motors in the ship. One method of dividing them was as follows: one circuit for engine-room motors; one for ventilating fans; one for hoist motors; and one for other sundry motors. The fuse boxes on this circuit were heavier than those for the lighting circuits. Junction and fuse boxes were used, but no small distribution boxes were necessary.

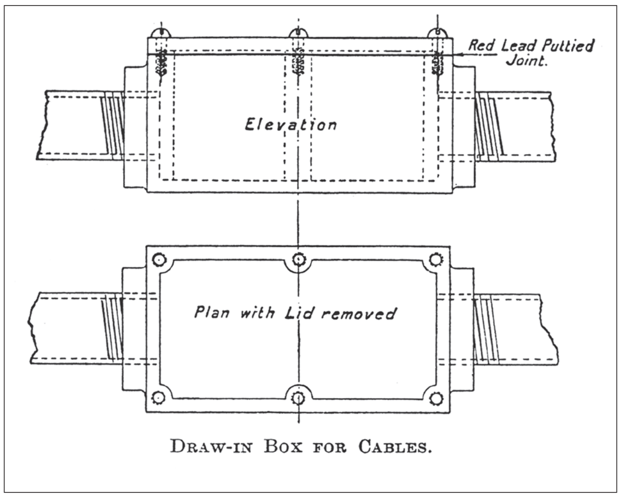


Fig. 17-34 **Draw-In Box**.

Another circuit which should be mentioned is that for the Sirocco fans for the stokeholds and the engine-room ventilating fans. These had separate individual control switches, an ammeter and a starting gear fitted on or near the main switchboard.

Cables and wiring

The main cables and branch wires were heavily braided, tinned copper. They were sheathed with vulcanized rubber and had a minimum insulation resistance of 600 megohms per mile (commonly the minimum resistance allowed by regulation). Branch wires in the machinery spaces were also tinned copper, but lead-sheathed, armored and externally braided for additional protection. Armored cables without a lead sheathing between the rubber and armoring were not used as they invariably caused problems, especially in places like engine rooms where heat, moisture and oil had to be contended with. In the boiler rooms the cables were run in steel pipes for protection against dampness and mechanical injury. Wires leading through watertight bulkheads had their own special considerations, as any area through which a group of cables passed needed to be protected against the leakage of water even when under pressure. Single-conductor cable was generally used, although some twin lead-covered and twin lead-covered-and-armored cable was occasionally employed. Twin flexible cable was used for the portable leads for arc lamps and cargo clusters.

Ordinary cable with braided finish was used throughout the interior of ship. These were run in wooden casings, behind moldings and panels, and sometimes in tubing. Wiring of this type was found in passenger accommodations, staterooms, passages, pantries and lavatories, officers' and engineers' cabins and mess rooms, storerooms, crew's accommodations, and behind panels in public rooms and entrances.

Plain lead-covered wire could be used anywhere braided cable was permissible. Lead-covered wire was, however, always used in those areas which were exposed to the weather such as the run under the Bridge for the sidelights, instrument and telegraph lights. Lead-covered wires could be secured by means of clips to the ironwork of the ship or to wood battens. The clips used were the brass double-ended type, varying in size according to the number and diameter of the wires which were under the clips.

Braided cable, however, was employed for the deck lights and was run in galvanized piping with a watertight connection made by means of a screwed joint between the piping and the fitting.

Clipped lead-covered wire was used for practically every circuit where casing was run, and if a 'surface' job was required (i.e. an installation with all the wiring exposed to view) it could be carried out with dipped lead-covered wires. If braided or lead-covered wires were used for machinery spaces, holds, or such like places where they would be exposed to mechanical injury, the wires were run in piping, either steel conduit or iron gas pipe.

When iron gas piping was used to run wires within, care was taken to see that it was free from burrs inside. The pipe was of ample size to allow the wires to be easily withdrawn for inspection or renewal. To facilitate this, draw-in boxes were fitted at intervals of not more than 20 to 25ft.

Armored cable was used in the machinery spaces, galleys and similar places where there was steam, moisture or heat present and where the cable was liable to be damaged mechanically. It was often necessary to run part of a circuit in braided cable and part in armored.

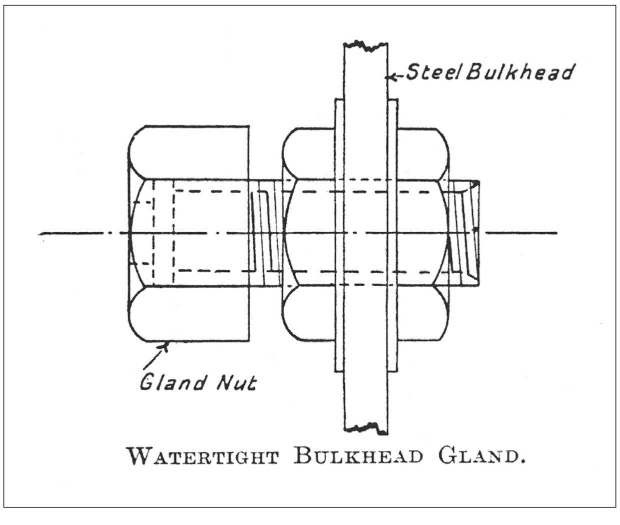


Fig. 17-35 **Watertight Gland**.

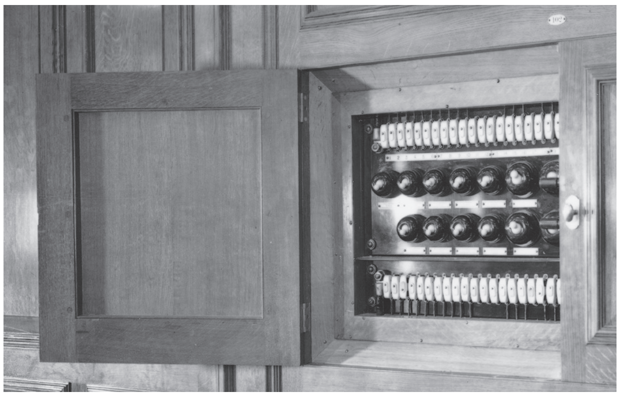


Fig. 17-36 **Wood Covered Panel** – One of the electrical distribution boxes on *Olympic.* This one on A Deck is neatly concealed behind a wooden panel in the main corridor leading from the forward First Class Entrance Hall to the First Class Lounge. *(*The Shipbuilder*/Authors' collection)*

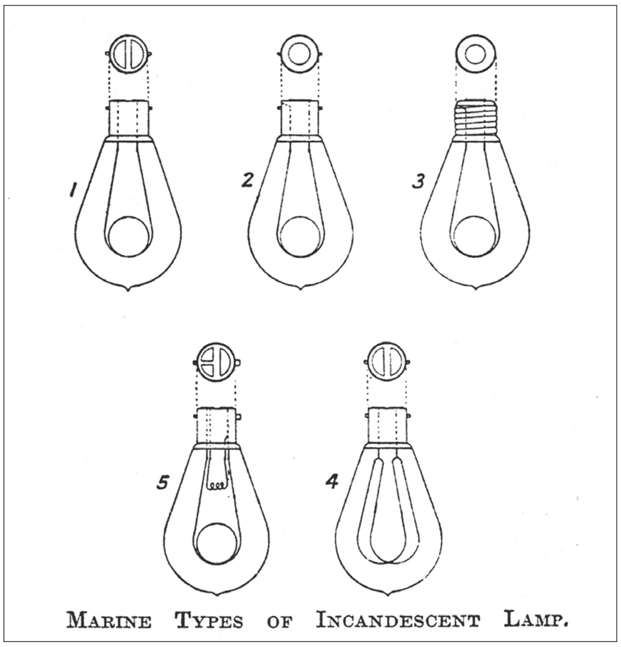


Fig. 17-37 **Lamp Types.** 1 – Double contact; 2 – Single, or center, contact; 3 – Screw socket (Edison type); 4 – Double filament; 5 – 'Full' and 'Glow' lamp.

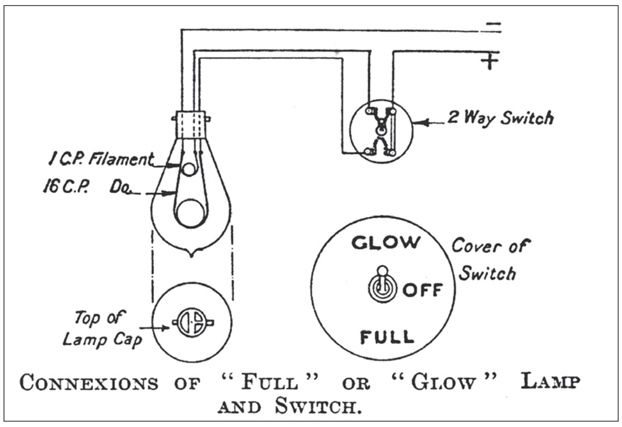


Fig. 17-38 **Glow Lamp** – Schematic diagram of the wiring for a typical glow lamp.

In these cases, the small junction boxes described above were used to connect different kinds of cable. An arrangement of this kind on a larger scale was used for the main cables, running from the main switchboard in the Electric Engine Room to the fuse boards in the various parts of the ship.

Another essential component of *Titanic*'s wiring was the watertight gland. These glands were used where it was necessary to pass cables through watertight bulkheads. In doing so, cables were collected together in a steel tube filled with bitumen to ensure watertightness and yet look neat.

In addition, when running cables through holes in iron beams, ordinary non-watertight bulkheads or ironwork of any description, it was required to bush the holes with lead or insert fiber or hardwood ferrules in them to prevent the cable from being damaged by coming into contact with and chafing against the iron. This precaution did not apply to armored cable, although some engineers insisted on having all holes bushed throughout the ship. Generally speaking, however, armored cables were passed through plain holes.

All wiring for lights was carried out on the 'loop-in' system, with as many as four lights looped on one fuse of the distribution board. When lights were in a straight or fairly straight line, they were simply looped up by wiring from one light to the next. When scattered, they

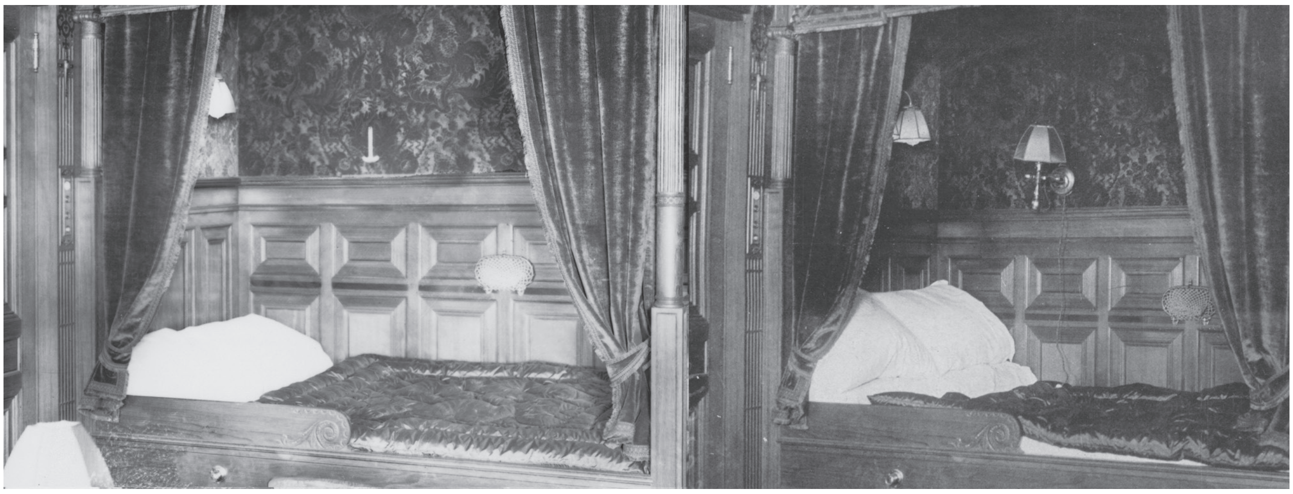


Fig. 17-39 **Portable Lamp** – The *Olympic*-class liners were provided with fittings for portable lamps which could be installed on the bulkhead and plugged in to a local wall socket. This image shows two views of *Titanic*'s stateroom B 59. The image at left shows how the room looked when it was photographed by Harland & Wolf. The image to the right shows a portable lamp fitted on the hanging clip that is vacant in the left image. (As a matter of interest, this same image, taken before the maiden voyage, shows the bed cover is in disarray. This stateroom was not known to have been occupied. However there was no reason for it not to have been occupied during the run from Belfast to Southampton, or perhaps even during *Titanic*'s time in Southampton. Very likely is the possibility that this stateroom was shown to the newspaper reporters, and perhaps one of them tried it out by sitting or reclining on the bed.) *(Daniel Klistorner collection)*

were wired up to a small junction or loop-in box. A pair of wires was run from the fuse board to the loop-in box and separate pairs taken from the box to each light.

In the machinery spaces or any other space where armored wire was used and where fittings had long, tubular stems, loop-in boxes were adopted as it was not good practice to run two pairs of armored wires down the tubes of fittings.

Fuse boards

Fuse boards and covers were custom-made to each situation depending on the particular surroundings and woodwork had to be matched. The only parts of the boards which were standardized were the slabs. These were obtained from the manufacturer ready-fitted with four, six, or eight fuses as required, as well as a bus-bar and main terminal. In some cases, the fuse boards and even the switches themselves were fitted in recesses behind paneling; with one of the panels being arranged to serve as a door. The fuses themselves were of the porcelain bridge type with visible fuse wires. For distribution boards the 5-amp size was used; the number of fuses ranged from four to eight according to the number of lights fed from the board.

In the machinery spaces, fuse boards were enclosed in cast-iron boxes. The iron boxes were usually watertight and had plain doors with wing nut closures. The wires entered the box from below to eliminate the possible risk of water finding its way inside and causing trouble.

In addition to the passenger-accommodation and machinery-space fuse boards already mentioned, there were a number of ordinary boards required for such places as the crew's quarters forward and the store spaces amidships aft. In all general places of this kind, the fuse boards were of teakwood or mahogany.

Lighting and fixtures

The light fixtures and electric lamps[10] on *Titanic* were of widely varying designs, from ornate fixtures in the First Class public spaces to simple utilitarian ones in the Third Class, crew and cargo spaces. The electric light bulbs fitted within them could be clear, semi-frosted, or totally frosted as the situation required. Light bulbs and bulb holders on British vessels were practically all of the bayonet-socket type, but on American and Continental vessels the Edison screw-socket type was widely used. The type using a single center-contact cap was required for the single wiring of the ship.

About 10,000 incandescent light bulbs were installed onboard *Titanic,* ranging from 16 candlepower to 100 candlepower.[11] The majority were of the Tantalum-filament type. Tantalum bulbs were more expensive than ordinary incandescent bulbs, but their reduced power consumption more than compensated for their higher cost. They were usually of 16 or 25 candlepower and were found quite suitable for use aboard ship except where there was any pronounced vibration.

In the First Class staterooms, in addition to the usual fixed lights, there were cleats fitted for portable electric lamps or fans. Special dimming lamps were also provided so that a light of small candlepower could be kept burning throughout the night.

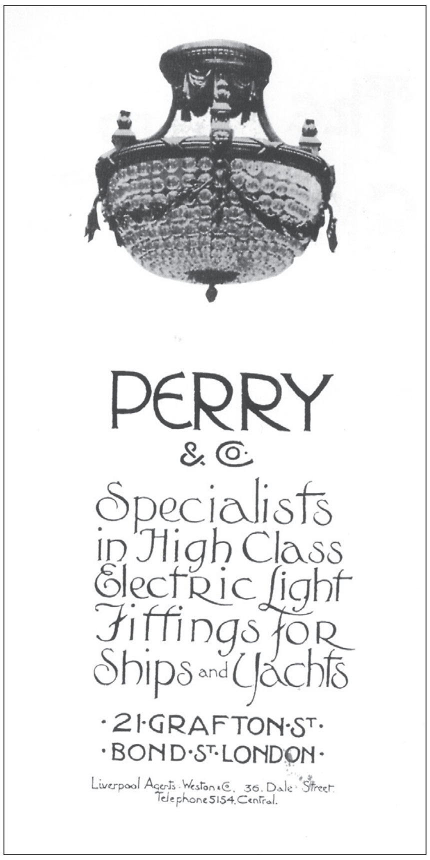
The light switches were attached to plates within convenient reach of each berth. All First Class staterooms on *Titanic* were provided with a reading lamp over the beds, something *Olympic*'s staterooms lacked in their original design. The main companionways in the First Class areas were lighted with small cut-glass bowls appropriately set in the deep panels of the ceilings.

The electric light fittings used on ships were of strong and substantial design. They were short as compared with shore fittings, owing to the small headroom available on board ship – in staterooms and general passenger accommodations the average height from deck to deck was 8ft exclusive of overhead beams and paneling. In the dining saloons and public rooms the height was often more than this, but owing to the motion and vibration common with ships at sea, they still had to be stiff and rigid to withstand the motion of the ship.

Generally speaking, the light fittings may be divided into three classes:

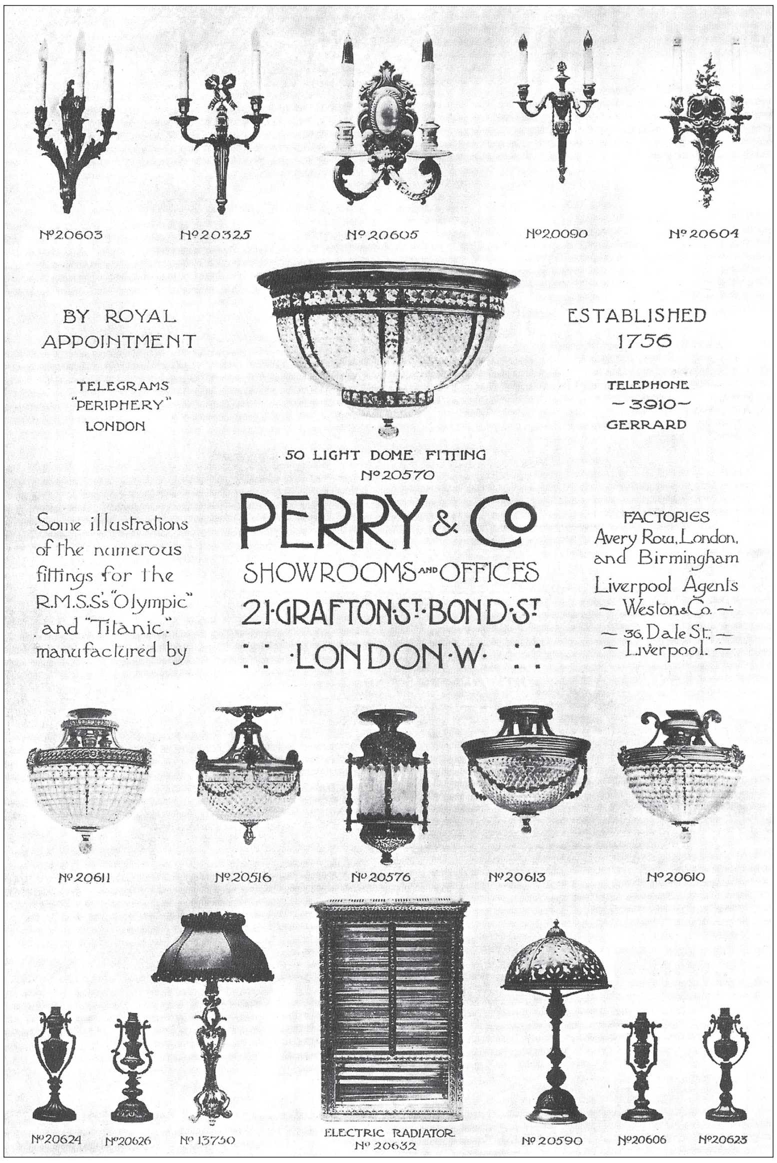
(1) Special ornamental fittings for the more ornate public rooms
(2) Standard fittings used in the public rooms as well as in general staterooms and cabins, corridors and companionways
(3) Watertight fittings used in machinery spaces, stores, galleys, on open decks etc.

Many light fixtures were highly ornamental and designed specifically for the rooms in which they were fitted. These varied so greatly in style that they are therefore described in greater detail in the chapters covering each individual deck; however, some general descriptive information is in order here. Many of the electric light fittings throughout the First Class spaces were of 'ormolu', a gilt-bronze finish. In the public rooms, main entrances, and suite rooms, these fittings were of a magnificent character, designed to agree in style with the particular period of decoration



PERRY
& Co
Specialists
in High Class
Electric Light
Fittings for
Ships and Yachts
·21·GRAFTON·ST·
·BOND·ST·LONDON·
Liverpool Agents:- Weston & Co. 36, Dale Street.
Telephone 5154, Central.

Fig. 17-40 **Advertisement for Perry & Co. (1)**. *(*The Shipbuilder*/Authors' collection)*



Nº20603
Nº20325
Nº20605
Nº20090
Nº20604

BY ROYAL
APPOINTMENT

TELEGRAMS
"PERIPHERY"
LONDON

ESTABLISHED
1756

TELEPHONE
—3910—
GERRARD

50 LIGHT DOME FITTING
Nº20570

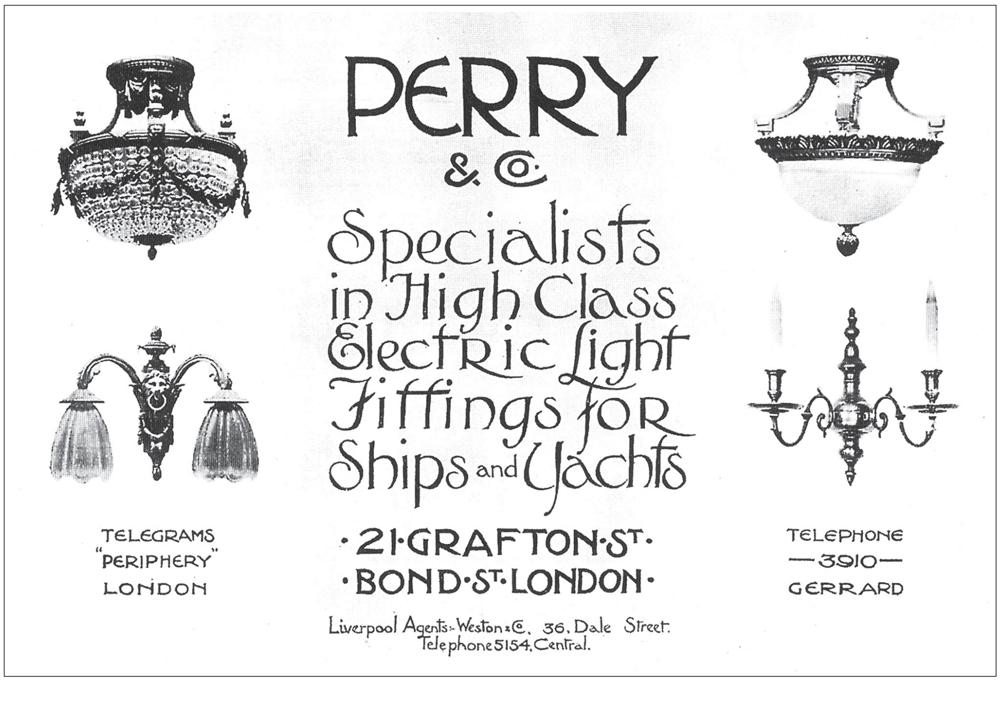
Some illustrations
of the numerous
fittings for the
R.M.S.S.'s "Olympic"
and "Titanic."
manufactured by

PERRY & Co
SHOWROOMS AND OFFICES
21·GRAFTON·ST·BOND·ST
·LONDON·W·

FACTORIES
Avery Row, London,
and Birmingham
Liverpool Agents
— Weston & Co. —
— 36, Dale St. —
— Liverpool. —

Nº20611
Nº20516
Nº20576
Nº20613
Nº20610
Nº20624
Nº20626
Nº 13750
ELECTRIC RADIATOR
Nº 20632
Nº 20590
Nº20606
Nº20623

Fig. 17-41 **Advertisement for Perry & Co. (2)** – This advertisement shows in good detail the design of many of the light fittings supplied for *Titanic*. *(*The Shipbuilder*/Authors' collection)*



PERRY
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in High Class
Electric Light
Fittings for
Ships and Yachts

TELEGRAMS
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·21·GRAFTON·ST·
·BOND·ST·LONDON·

TELEPHONE
—3910—
GERRARD

Liverpool Agents:- Weston & Co. 36, Dale Street.
Telephone 5154, Central.

Fig. 17-42 **Advertisement for Perry & Co. (3)**. *(*The Shipbuilder*/Authors' collection)*

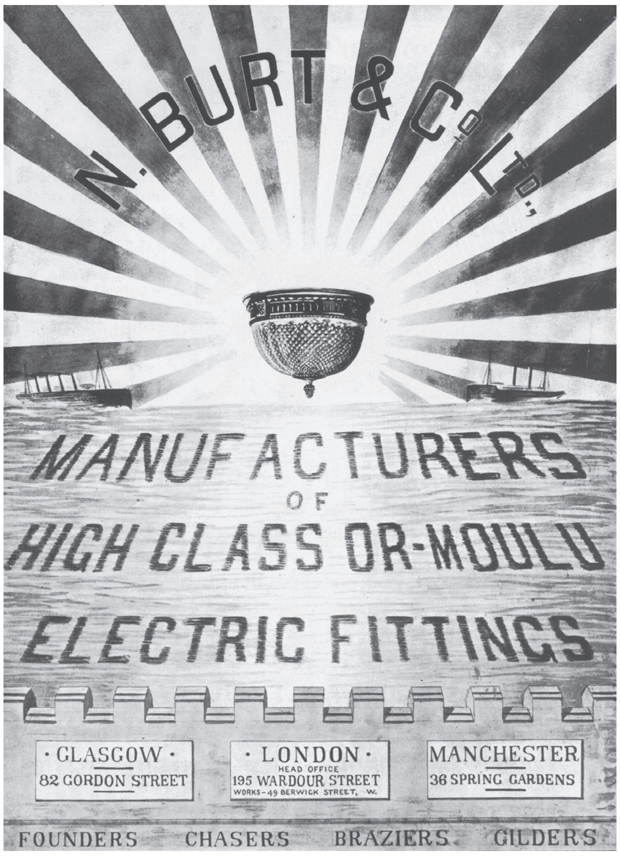


Fig. 17-43 **Advertisement for N. Burt & Co. (1)**. *(*The Shipbuilder*/Authors' collection)*

employed, and ranging from austere Italian Renaissance to elaborate Louis XVI. The main staircase fittings were styled after original French models. No trouble or expense had been spared in their selection, some costing hundreds of pounds each. A number of other light fittings in the First Class passenger accommodations were noted as being made of 'majolica', believed to refer to white, glazed ceramic fixtures which did not tarnish like metal.[12] It must be emphasized that the terms 'ormolu' and 'majolica' referred to the material and/or finish and not the style of lamp.

Electric light sconces were used throughout the more ornate public spaces; these were termed 'appliqués'. Many ceiling fixtures were termed 'electroliers', this being a light fixture that was hanging from the ceiling in one form or another. The term 'electrolier' was a variant on the term 'chandelier' to reflect the fact that it was electrically illuminated, although unlike 'chandelier, 'electrolier' did not necessarily mean a hanging ceiling fixture with branching frames supporting separate bulbs. The ceiling lights in the First Class Entrances which had faceted cut-glass bowls, for example, were also termed 'electroliers'. Those hanging fixtures fitted with low-hanging glass bowls were frequently termed 'plaffoniers;' a 'pendant light' was a simple yet ornate fixture with a small globe fixed just below the ceiling.[13] Where a simpler non-hanging ceiling fixture was required, ceiling 'roses' were extensively used, as in companionways, less-ornate public rooms and in many staterooms. A ceiling rose was nothing more than a simple, glazed ceramic light fixture. It was essential that the ceiling rose be made of non-combustible material and be a good insulator. A ceramic rib separated the terminals within the fitting to prevent short circuits. Finally, in Third Class cabins and many crew areas, bare light bulbs were frequently used with plain sockets of the same material as the ceiling roses.

The ormolu electric fittings in the First Class Dining Saloon, Reception Room, Lounge, Entrances, corridors, staircases, special staterooms, sitting rooms and the Cooling Room connected with the Turkish Baths were designed and manufactured by Perry & Co., London, who designed – among other things on the ship – the elegant twenty-one-light bronze candelabrum mounted to the newel post of the central baluster at the foot of the grand staircase on D Deck. Ormolu fixtures not supplied by Perry & Co. were supplied by N. Burt & Co. Ltd of London. Nearly all special fittings were sent from the makers already wired, so that it was only necessary to join up the wires behind the base plate. All bulb holders used were not less than ⅜in in the neck, otherwise they would be too small for looping the wires. Wherever possible a few inches of slack wire was left behind the base of the fitting to facilitate removal and replacement.

Special dual-filament light bulbs, called 'glow lamps', were fitted to certain light fixtures in First Class staterooms. 'Glow lamps' had two filaments, one of 16 candlepower and a small one of only 1 candlepower to act as a 'night light'. This type of bulb had three contacts on the cap, and the bulb holder was of a special type with three plungers to match.

Every First Class stateroom was provided with a 12in-diameter electric fan. While most were of the 'beam type', intended to be mounted to the ceiling of the stateroom in a convenient location, a number of fans were in fact 'table fans', such as those found in the special staterooms and sitting rooms fitted out in a period style. Fans were generally fitted with an open grille, except in cases where passengers were likely to injure themselves while handling them. In these instances, a mesh grille was also fitted protecting the blades.

Illuminated signs were fitted opposite the doors of lavatories to indicate whether they were for ladies or gentlemen; these consisted of rectangular metal boxes with white glass panels. Signs of this type were also mounted outside elevators, bathrooms, public rooms, entrances and like areas.

Watertight light fittings were represented by three distinct types:

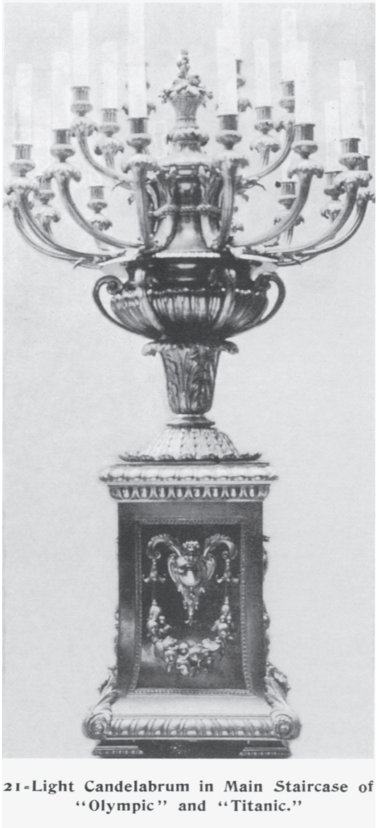
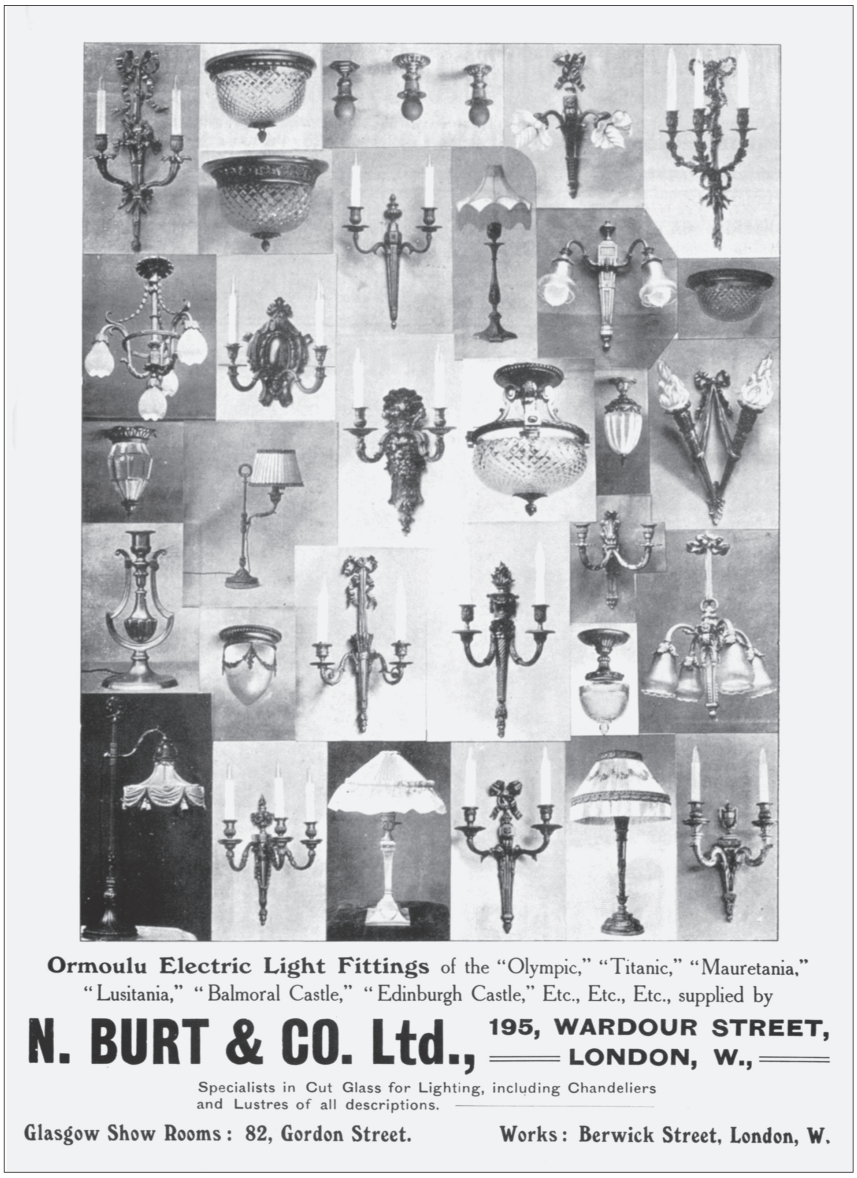

21-Light Candelabrum in Main Staircase of "Olympic" and "Titanic."

Fig. 17-44 **Perry & Co. Advertisement** – Among other fixtures, Perry & Co. supplied the elegant 21 light candelabrum mounted to the newel post of the central baluster at the foot of the forward First Class staircase D Deck. (The Shipbuilder/*Authors' collection)*



Ormoulu Electric Light Fittings of the "Olympic," "Titanic," "Mauretania," "Lusitania," "Balmoral Castle," "Edinburgh Castle," Etc., Etc., Etc., supplied by

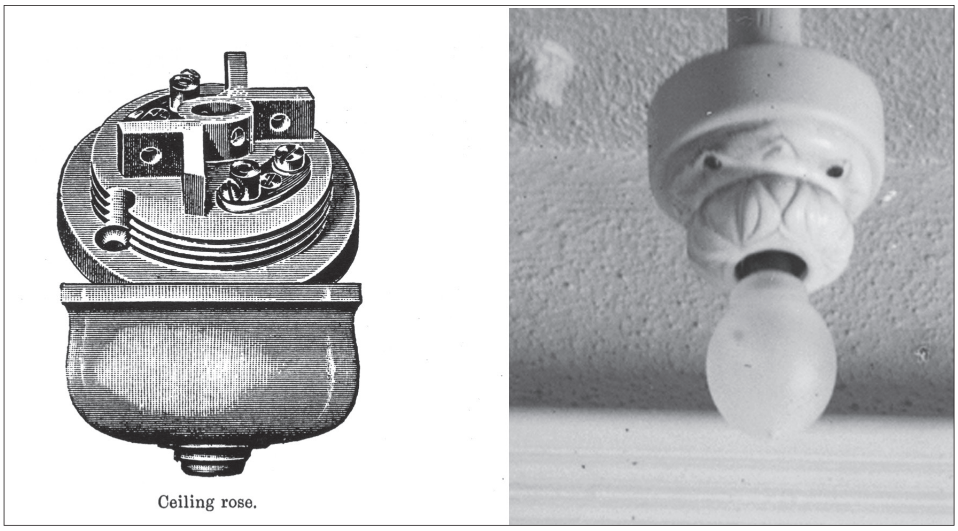
N. BURT & CO. Ltd., 195, WARDOUR STREET, LONDON, W.,

Specialists in Cut Glass for Lighting, including Chandeliers and Lustres of all descriptions.

Glasgow Show Rooms: 82, Gordon Street. Works: Berwick Street, London, W.

Fig. 17-45 **Advertisement N. Burt & Co. (2)** – Like the Perry & Co. advertisement previously shown, this illustrates many of the light fittings used on the *Olympic*-class ships. *(*The Shipbuilder*/Authors' collection)*

Fig. 17-46 **Ceiling Rose** – At left, a common ceramic ceiling rose very similar to those used to this day. At right, one of *Olympic*'s ceiling roses that illuminated a stateroom. These fittings varied in design and were used extensively throughout the passenger areas of the ship. The one in this image is from a D Deck cabin, and as the overhead was higher throughout D Deck, this fixture was extended below the ceiling by means of a short pipe. The light fixtures in the Galley areas were similarly lowered. *(Image and illustration from authors' collection)*



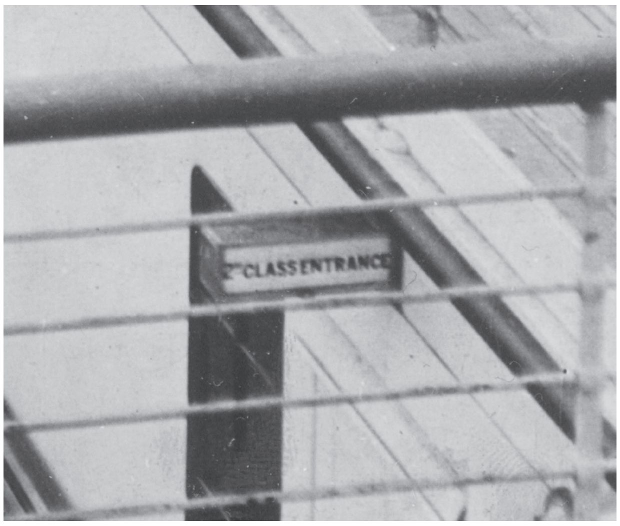


Fig. 17-47 **Illuminated Sign** – One of *Titanic*'s illuminated signs. This one is indicating the Second Class Entrance on B Deck.

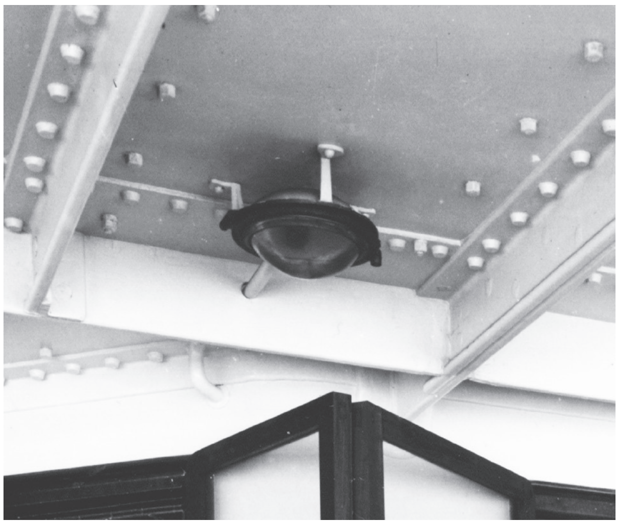


Fig. 17-49 **Oyster Light on Promenade Deck** – One of the 'oyster' lights located over the A Deck promenade on *Olympic*.

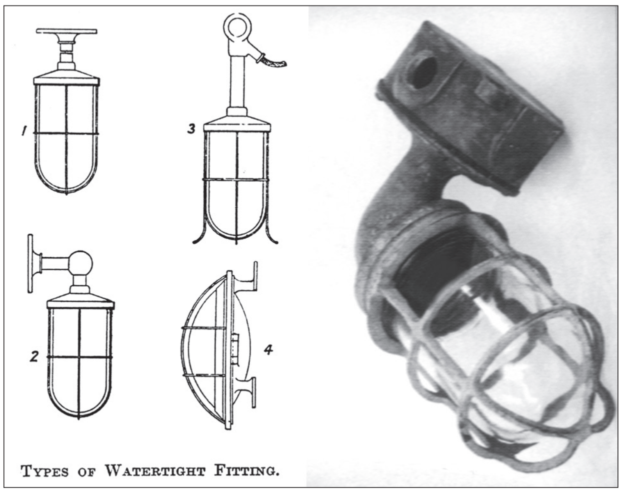


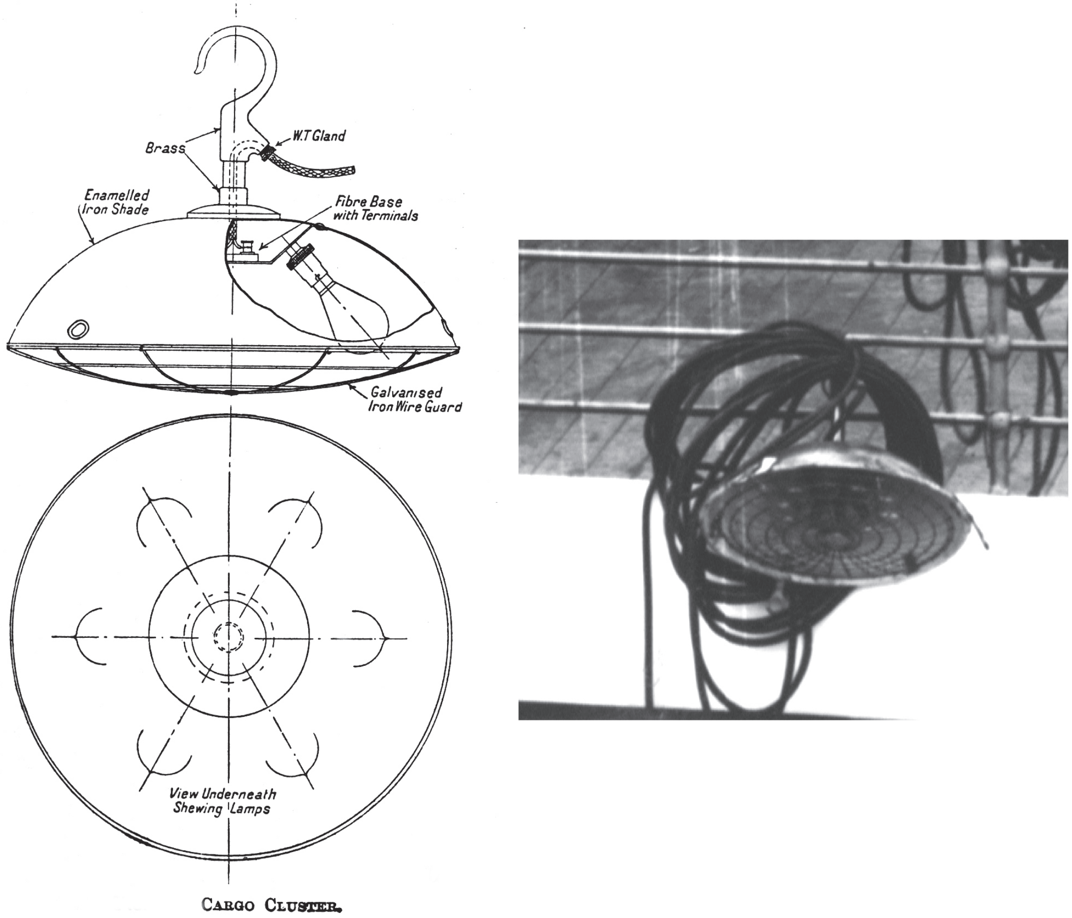
Fig. 17-48 **Types of Watertight Fittings** – (1) A pendant fitting of the type used in the machinery spaces, crew's quarters, stores etc. This pendant fitting was made with a separate back plate and a short stem for ordinary use, with the stem screwed into the fitting portion. The stem (usually ½in gas pipe) could be made to any required length to suit a particular location. Similarly, the brackets could be made for any desired projection or drop. Short fixed brackets with knuckle joints were used where small projections were desired, as in (2). (3) The watertight portable hand lamp, used in the machinery spaces, storerooms, etc. This was generally considered to be a very good type of hand lamp, made of brass with cast brass guard. A hook was fitted beside each hand lamp plug to hang the lamp and flexible wire when not in use. (4) The 'oyster' or bulkhead light. This was mostly used on the open deck, but also occasionally in the machinery spaces. Fitted on deck, it could be in a position either overhead or on the side of one of the deck houses. It was made with or without a brass guard, also with or without an iron cover. All the foregoing watertight fittings could be made either of iron or brass according to the ship owner's specification. If made of iron they were painted; if made of brass they could be painted, finished in polished brass, or finished in steel-bronze as desired. The image to the right is a light from a machinery space from an actual White Star Line ship of the period.

(1) The fittings used in the machinery spaces, crew's quarters, stores, etc., which were typically hanging (pendant) fittings. The pendant fitting was made with a separate backplate and, for ordinary use, a short stem which screwed into the fitting portion. The stem (usually gas pipe) was made to length to suit each particular location. Similarly, the brackets were made for any desired projection or drop. Short, fixed brackets with knuckle joints were used where a small projection was desired.

(2) The watertight portable hand lamp, which was used in the machinery spaces and storerooms etc., was generally made of brass with cast brass guard. A hook was fitted beside each hand lamp plug to hang the lamp and flexible wire on when not in use.

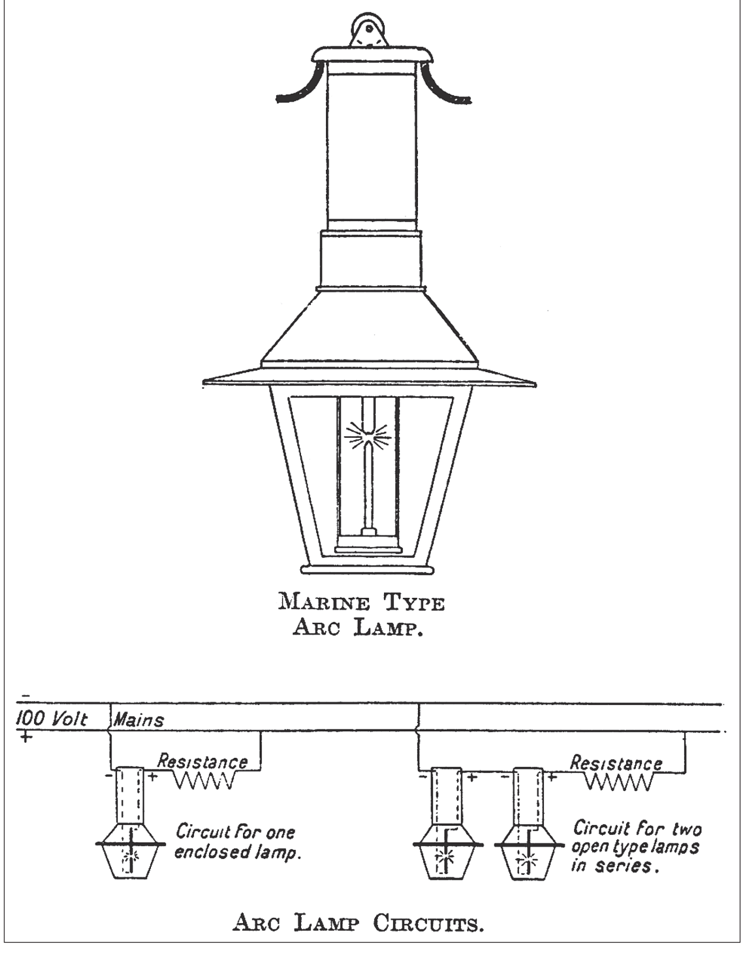
(3) The bulkhead, or 'oyster', fitting supplied by William McGeoch & Co. Ltd. These were used on the open decks and mounted either overhead, on the side of one of the deckhouses, or to the railings. They were made with or without a brass guard, also with or without an iron cover. The lights within the forward Well Deck, for instance, were of the guarded type.

Other special light fixtures were used for servicing and loading of cargo. The three-bulb cargo light was simply a light fixture with three incandescent light bulbs fitted beneath a reflective shroud. *Titanic* was also provided with carbon arc lamps for use when coaling or loading cargo at night; these were very bright, and were rigged from special halyards or from the coaling outriggers.


Brass
W.T Gland
Enamelled Iron Shade
Fibre Base with Terminals
Galvanised Iron Wire Guard
View Underneath Shewing Lamps
Cargo Cluster.

Above Fig. 17-50 **Cargo Cluster Light** – The cargo cluster light was a common utility light aboard ship, and sported any number of light bulb combinations; six, eight, or ten lamps was the usual number. These lights were generally 20 to 30in in diameter overall.

Right Fig. 17-51 **Arc Lamp** – The terminal connection boxes for the arc lamps and cluster lights were similar in design, and of the cast-iron watertight pattern. They contained a strong plug-and-socket coupling and a switch. One important difference in the form of the plugs belonging to the arc lamps was that they were designed so that they could not be inserted into the cluster light boxes in error. This rule was strictly observed where line resistances were used in circuit with the arc lamps, but did not apply where the lamps had self-contained resistances. Line resistances were almost invariably required in order to obtain the correct voltage across the lamp terminals. Enclosed arc lamps required about 70 volts, and were used singly on 100 and 110 volt installations. The open-type arc lamps required from 45 to 50 volts, and were used singly on 55 and 60 volt installations, and with two in series on 100 and 110 volt installations. *(Authors' collection)*


Marine Type Arc Lamp.
–
100 Volt
Mains
+
Resistance
Circuit For one enclosed lamp.
Resistance
Circuit for two open type lamps in series.
Arc Lamp Circuits.

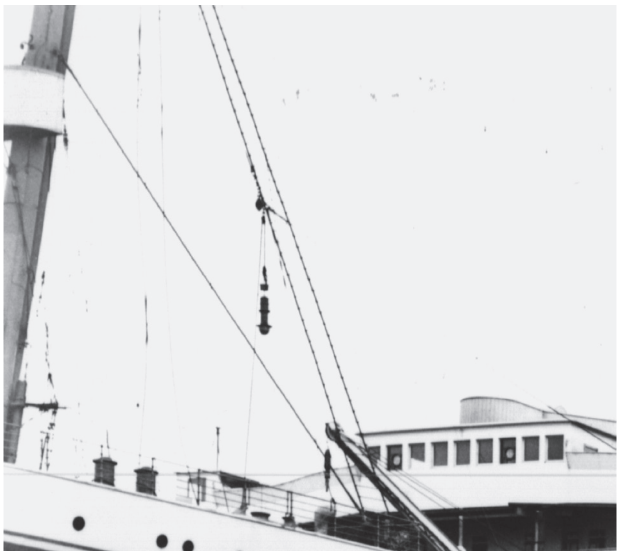


Fig. 17-52 **Arc Lamp in use on *Olympic*** – In this image, an arc lamp has been rigged to a cargo span.

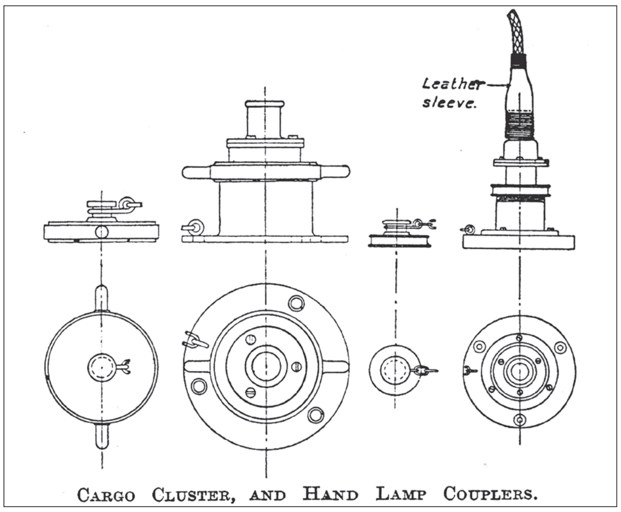


Fig. 17-53 **Cargo Cluster and Hand-Lamp Couplers** – This drawing shows the two patterns of watertight couplers of the type used on *Titanic*. The larger size was for currents up to about 10 amperes, and was typically used for cargo cluster lights; the smaller size was for currents up to about 3 amperes and used for portable hand lamps. Leather sleeves were fitted on the nozzle of the plug where the flexible lead entered, as shown with the one at right. The sleeves were tightly bound with cord both on the nozzle and on the flexible cord. This served to prevent the cord being pulled out of the plug and also from being bent continually at one spot.

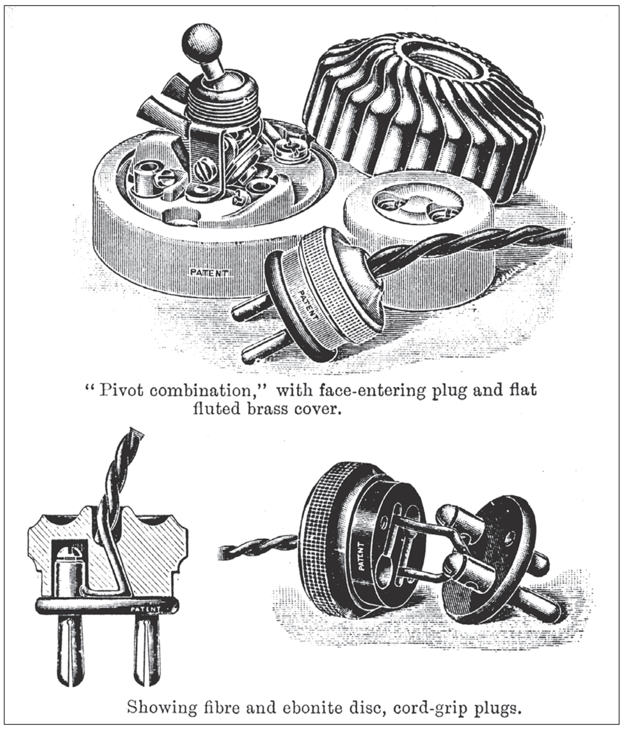

PATENT
PATENT
“Pivot combination,” with face-entering plug and flat fluted brass cover.
PATENT
PATENT
Showing fibre and ebonite disc, cord-grip plugs.

Fig. 17-54 **Typical Cabin Plugs and Sockets** – Variations of the cabin style switch, plug and socket used aboard ships of the era.

Plugs and sockets

There were two sizes of the ‘watertight pattern’ and one of the ordinary ‘cabin pattern’ in general use aboard *Titanic*. The former were often called ‘couplers;’ the larger was used for cargo clusters or arc lamps and the smaller for portable hand lamps. The large size was used for currents up to about 10 amps and the smaller for currents up to about 3 amps. Watertight electrical sockets were located about the weather decks for exterior work, the outlets for the arc lamps being separated from the sockets used for lamps with ordinary incandescent bulbs. The reason for the separation was that the outlets for the arc lamps were made in such a manner that the plug could not be inserted upside down so as to reverse the polarity. For cabin plugs, a small 3-amp, two-pin or concentric pattern was fitted for connecting a cabin fan or table lamp. A combined switch and plug was often used; of these, there were several variations.

As *Titanic* used the single-wire or ‘ship return’ system, any fittings mounted to joinery and not screwed directly to the steel of the ship required a separate grounding wire between the ship and the fixture.

Switches

Generally speaking, there were two kinds of switches in use, the watertight switch and the cabin switch. All switches fitted on open decks or in any exposed places were of the watertight type. Nearly all watertight switches had a stuffing gland through which a key spindle passed. The inlet for the wires was threaded to take iron tubing or conduit. Another arrangement used consisted of a watertight cast-iron box with lid, with ordinary switches fitted inside. This box had a threaded inlet similar to the watertight switches.

The cabin switches were of the tumbler or thumb pattern with covers finished to match the fittings in the

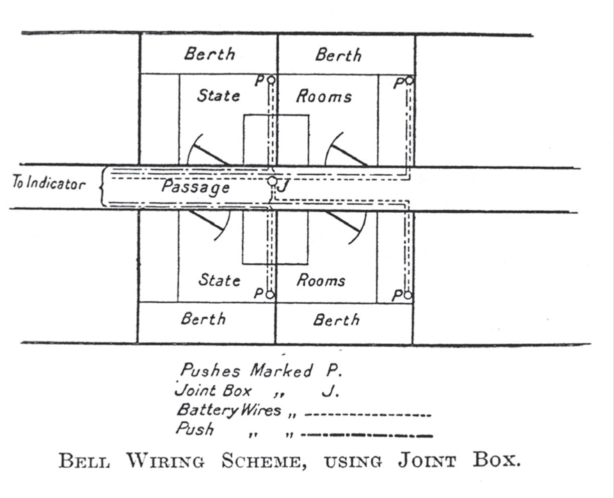


Fig. 17-55 **Bell Wiring with Joint Box** – This schematic diagram illustrates the typical bell wiring for a group of staterooms.

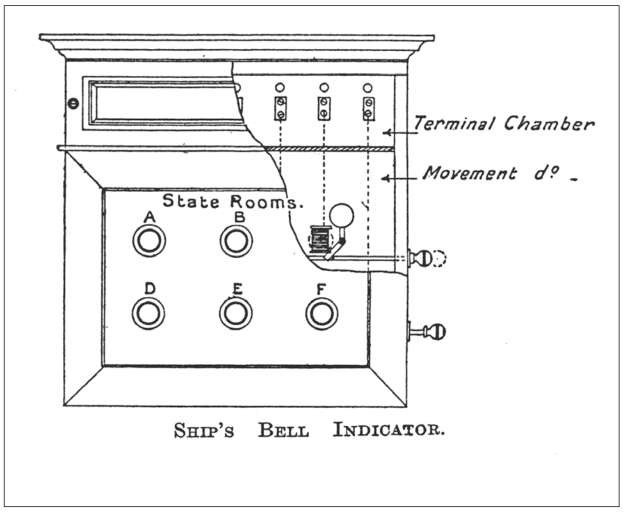


Fig. 17-56 **Bell Indicator** – A typical ship's bell indicator panel from the era.

room. The ordinary practice in staterooms was to mount the switch and bell push on one polished block in a convenient position near the berths.

In staterooms having berths on either side, for the convenience of passengers two switches of the two-way type were fitted, one on each side of the room near the head of each bed, so that either passenger could turn the light on and off without getting out of bed.

Electric bells

The electric bell installation on *Titanic* comprised no less than 1,500 bell-pushes throughout the ship. Added to these were the indicators, bells and batteries in the system, the wiring and connections being the same as those used on shore. However, the style and quality of the apparatus used and the details of the wiring did differ somewhat.

The wire for electric bells was braided and insulated with vulcanized rubber, and was almost as good in quality as that used for lighting purposes. The amount of rubber used was less, so that the overall finished diameter of the wire was less than that of the lighting wires. Because the bell wires ran along with the lighting wires, it was necessary to distinguish them as being separate. This was usually accomplished by connecting them with red colored wire of No.18 SWG. The return wires from pushes to indicator were usually of No.20 SWG. The power was supplied from the ship's lighting circuit at a reduced voltage, with a battery backup.

The bell-pushes most commonly used for staterooms were of polished ebony within decorative surrounds mounted alongside the electric switches. Indicators and bell fixtures were usually of teakwood unless fitted in some conspicuous position, in which case the surroundings were matched. The indicators were, however, nearly always fitted in a pantry where ornamentation was unnecessary. The bells were of the ordinary pattern with 3 or 3½in gongs, and were of low resistance in order to allow the indicator to work efficiently.

The indicators were of the 'drop' or 'mechanical replacement' type. There was one hole on the indicator dial for each stateroom. Where relevant, separate holes were provided for the Captain, Chief Engineer and any other of the officers' rooms in which bell pushes were fitted. Dining Saloons had one hole for the port-side and another for the starboard-side pushes.

Loud-speaking telephones

Telephones of the loud-speaking type were largely used in ship work. They were especially suitable for machinery spaces and other similar places, which were very noisy. The wiring of these telephones was usually carried out with three or four lead-covered cables supported by means of brass clips. Terminal boxes were always provided to facilitate the interconnecting of the instruments, batteries, etc.

Titanic was fitted with numerous telephones for communicating between certain areas of the ship, some on a central exchange system and others with direct connections that did not require the services of a switchboard. Of the latter type, the following telephone connections were provided on what was termed the 'navigating group':

From the Wheelhouse to the Reciprocating Engine Room
From the Wheelhouse to the Forecastle Deck

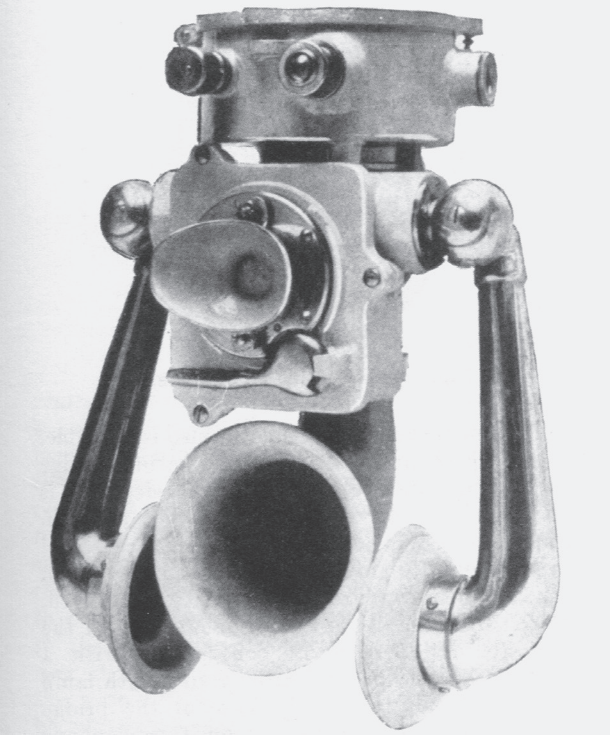


Fig. 17-57 **Loud-Speaking Telephone**. *(*The Shipbuilder*/ Authors' collection)*

From the Wheelhouse to the Crow's-nest
From the Wheelhouse to the Docking Bridge
From the Chief Engineer's Quarters to the Reciprocating Engine Room
From the Reciprocating Engine Room to Boiler Room Nos 1, 2, 3, 4, 5 and 6

The telephones on the navigating group were supplied by Alfred Graham & Co. and were of the 'Patent Loud-Speaking Navy' design. An exception to the Navy-type telephone was in the Chief Engineer's quarters, where his was of the universal 'cabin' type in which calls were given by means of an interrupter as well as by voice.

The telephones on the Forecastle Deck and the Docking Bridge were mounted in polished brass cases, each mounted on a pillar. In the case of the telephone for the Forecastle Deck, it could be used in either of two

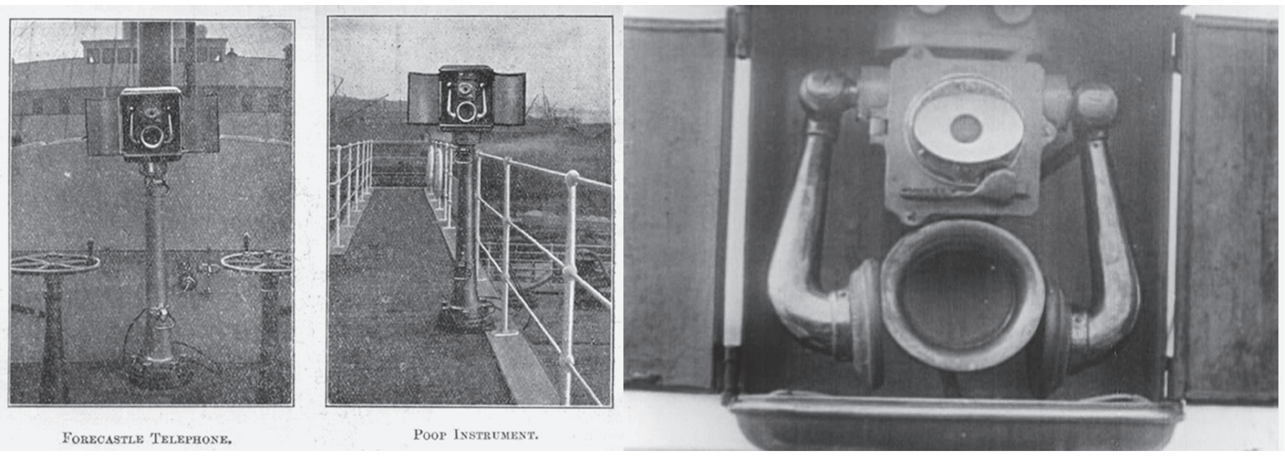


Fig. 17-58 **Telephones on Forecastle Deck and Docking Bridge** – At left, a telephone mounted forward of the No.1 Hatch on *Olympic*. Another position was available immediately abaft the center anchor crane at the bow. At center, the telephone on *Olympic*'s Docking Bridge. At right, a close up of the same. *(*The Electrician*/Authors' collection)*

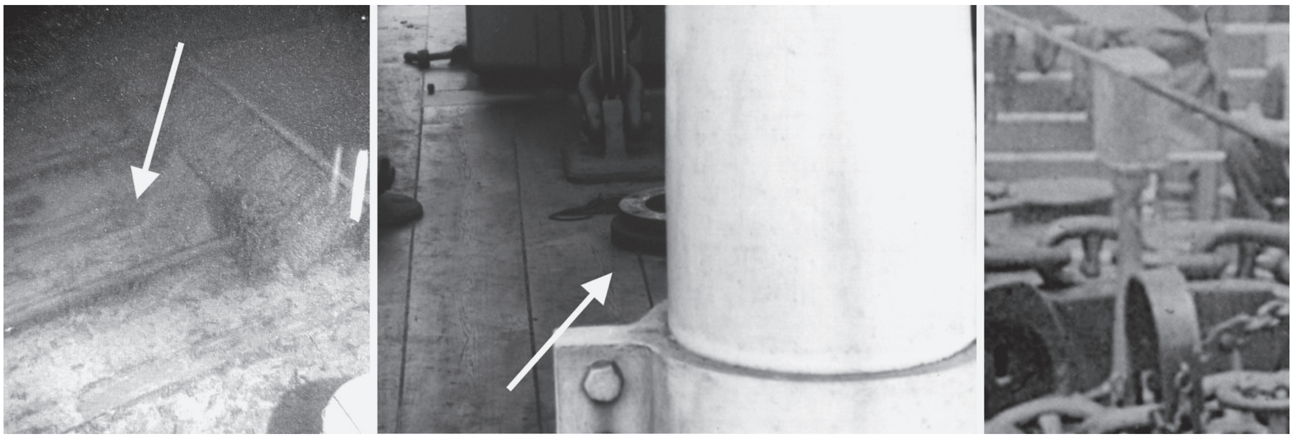


Fig. 17-59 **Portable Telephone Locations on Forecastle Deck** – These images show the two locations on the Forecastle Deck at which a portable telephone pillar could be fitted. At left, an image from the wreck showing the remains of the mounting ring just forward of the No.1 Hatch. At center, the forward position abaft the anchor crane on *Olympic*, and at right, an enlarged photographic detail showing a telephone in use at the same location. *(Wreck image courtesy of Steve Rigby; center and right images authors' collection)*

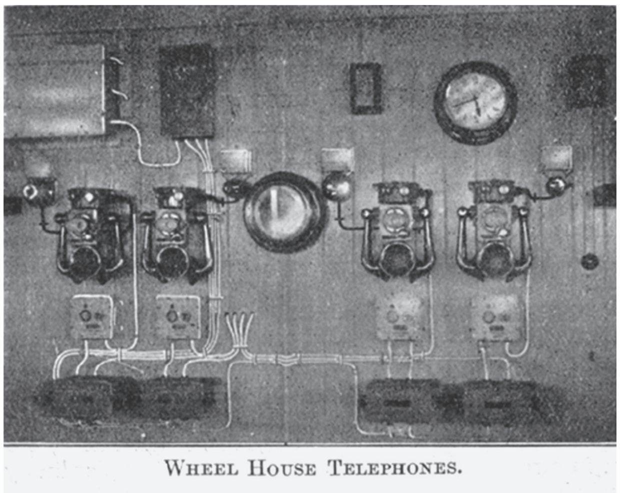


Fig. 17-60 **Telephones in Wheelhouse** – The line of telephones against the after bulkhead of *Olympic*'s Wheelhouse. *(*The Electrician*/Authors' collection)*

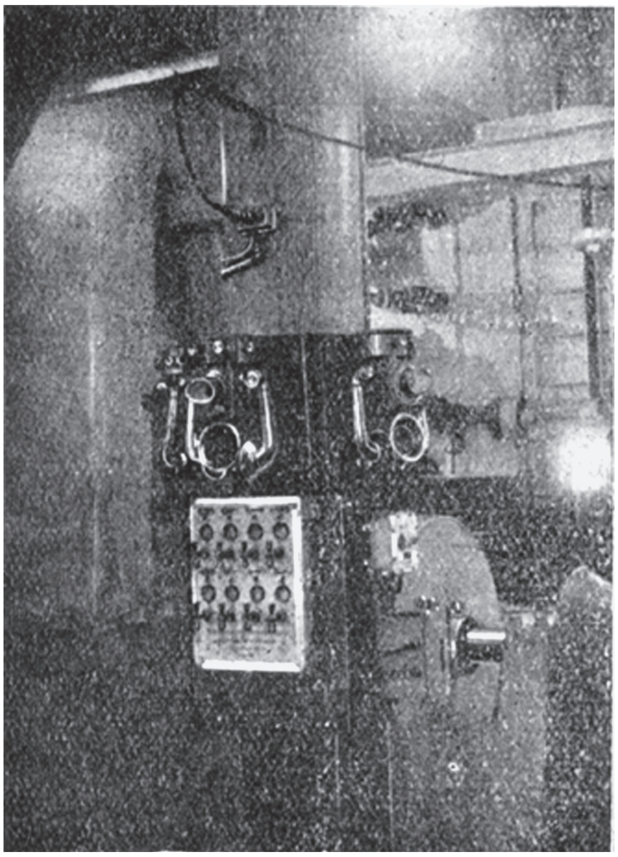


Fig. 17-61 **Engine Room Telephones**. *(*The Electrician*/ Authors' collection)*

positions, one immediately forward of the No.1 Hatch and one abaft the anchor crane; this entire case and pillar were portable and were stowed at sea. The Crow's-nest telephone was mounted in a brass hood on the after starboard side of the cage, and was also portable.

The Wheelhouse was fitted with four telephones. Each instrument was provided with an indicating device, in addition to a flag and signal lamp indicating that a call was being received. There were three telephones in the Reciprocating Engine Room. The instrument for communicating with the boiler rooms operated in conjunction with a combined switch and indicator giving both a flag and lamp signals. In each boiler room, the telephone was mounted within a metal hood, and a special calling receiver was provided at each station, as well as a visual indicator.

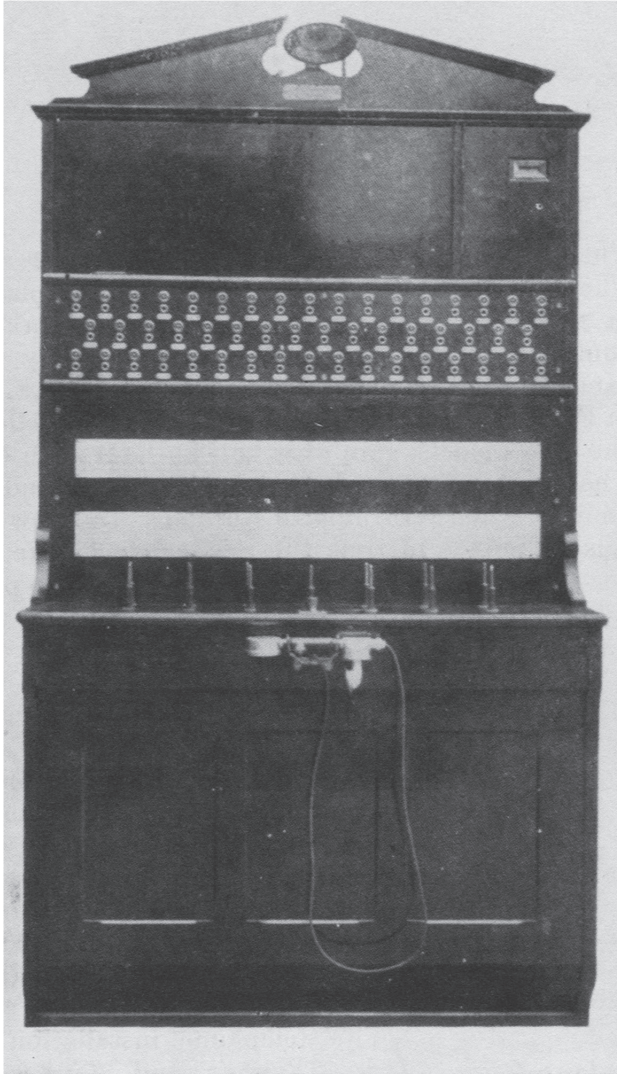


Fig. 17-62 **Telephone Exchange Switchboard**. *(*The Shipbuilder*/Authors' collection)*

The electricity for powering the telephones came from the ship's lighting circuit, which was reduced in voltage by resistors to a level suitable for telephone work. The noise inherent with a machine-generated supply was eliminated by the introduction of inductance coils. The phones were also given a stand-by battery that could be activated by a switch if the main generating sets went down.

These telephones were relatively new in 1912, having come into use after the turn of the century. It was stated by some mariners that communication with these phones was often unintelligible. While docking or disembarking, it was not uncommon to see the Captain or Bridge officer relying on the old standard of the megaphone, of which *Titanic* was provided with two.

Cabin telephones and central exchange switchboard

The main telephone switchboard was located in a room just forward of the First Class Elevators on C Deck, and was capable of handling 50 lines. These included the rooms of Senior Officers and various service rooms.[14] A light activated on the switchboard when a call was incoming. The user on the other end was only required to talk into the mouthpiece and state the room with which he desired to be connected. The user's voice would activate a speaker in the switchboard room, where the operator would simply connect the cable from the user's line to the appropriate jack after hearing the request. As with the telephones on the navigating group, the switchboard had an emergency battery backup located within the exchange switchboard casing. The telephone sets in each cabin were of Graham's Intermediate Loud-Speaking type, and comprised of a handset with a circular metal push and terminal box.

The Central Exchange was capable of handling calls between the following telephone stations:[15]

Captain's Quarters
Chief Engineer's Quarters
Chief Engineer's Office
Purser's Office
Assistant Purser's Office
Chief Steward
First Class Smoke Room Bar
First Class Dining Saloon Bar
Chief Second Class Steward
Chief Third Class Steward
Grocery Room
Chef's Office
Baker's Shop
Butcher's Shop
Third Class Galley
Surgeon
First and Second Class Surgery
Second Class Smoke Room Bar
À la carte Restaurant Pantry
Steward's Office
Marconi Operating Room
Enquiry Office
Third Class Surgery

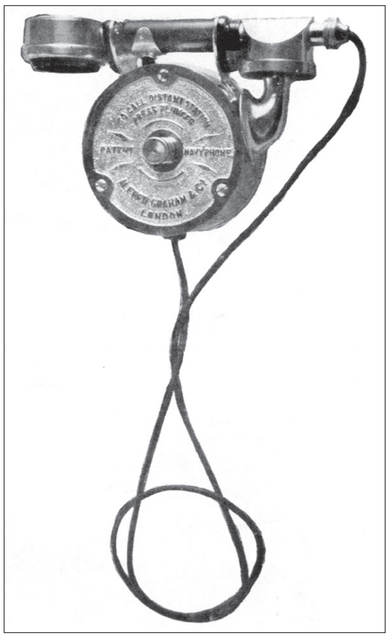
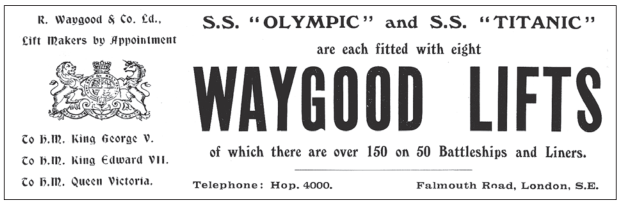


Fig. 17-63 **Cabin telephone** – A telephone of the 'cabin' type, used in the rooms of chief officials and various service rooms. (*The* Shipbuilder/*Authors' collection)*



R. Waygood & Co. Ld.,
Lift Makers by Appointment

To H.M. King George V.
To H.M. King Edward VII.
To H.M. Queen Victoria.

S.S. "OLYMPIC" and S.S. "TITANIC"
are each fitted with eight
WAYGOOD LIFTS
of which there are over 150 on 50 Battleships and Liners.

Telephone: Hop. 4000. Falmouth Road, London, S.E.

Fig. 17-64 **Advertisement for Waygood & Co. Elevators** – Surprisingly these were not called 'lifts' on *Titanic,* the wording in the advertisement to the contrary. 'Lift' is the common British term for elevator, the latter term thought to be an American colloquialism.

Besides the telephones on the exchange system and those on the navigating group, there was also a separate group of circuits provided to communicate directly between the following stations without the necessity of being connected by an operator at the central switchboard:

First Class Pantry (port side) to First and Second Class Galley[16]
First Class Pantry (port side) to Baker's Shop
First Class Pantry (port side) to Butcher's Shop
First Class Pantry (starboard side) to First and Second Class Galley
Second Class Pantry to Baker's Shop
Second Class Pantry to First and Second Class Galley

These telephones were identical to the cabin telephones, however the telephone on the port side of the First Class Pantry had a three-way switch and indicator box fitted owing to the three locations with which it communicated. The Baker's Shop and Second Class Pantry had two-way switches and indicators fitted for the same reason. Employees from Graham & Co. personally installed the telephones on *Titanic* while at Belfast.

Passenger elevators

Titanic's First and Second Class passengers were provided with lifts, or elevators. Second Class passengers had only one at their forward staircase, while First Class passengers had three located side-by-side immediately forward of the grand staircase. Though the Second Class elevator was used a great deal, the First Class elevators were found to be less popular. An observer on *Olympic* would write in 1911 that the First Class elevators were: 'seldom used by passengers, as they are fitted in a bad position and too much cased in. They are scarcely ever seen or thought about by those passengers who are berthed abaft the main staircase.' *Britannic* was built with an after First Class elevator to remedy this problem. It was also noted by passengers that the elevators would stick when the ship rolled in heavy weather. This problem was later rectified on *Olympic*.

Located within the First Class area of the ship were three 15cwt elevators numbered 1, 2 and 3. They were situated side-by-side within a foyer located forward of the main staircase, and traveled 37ft 6in between A Deck and E Deck. Each cab measured about 5ft 4in wide by 6ft deep by 7ft high, and had a capacity of ten persons. The paneling of each cab was enameled white and enriched with gilt detail in Empire design. The facing panel as well as the two side panels was fitted with a long mirror above the dado. Each cage had a glass roof and ventilator, and was furnished with a portable upholstered seat, battening protector for baggage and a gilt-metal-framed electrolier with a cut-glass bowl. The cages were fitted with Bostwick gates which were electrically locked and had to be closed before the lift motors could be started, while a separate sliding gate of decorative wrought-ironwork was fitted to the bulkhead opening at each deck.

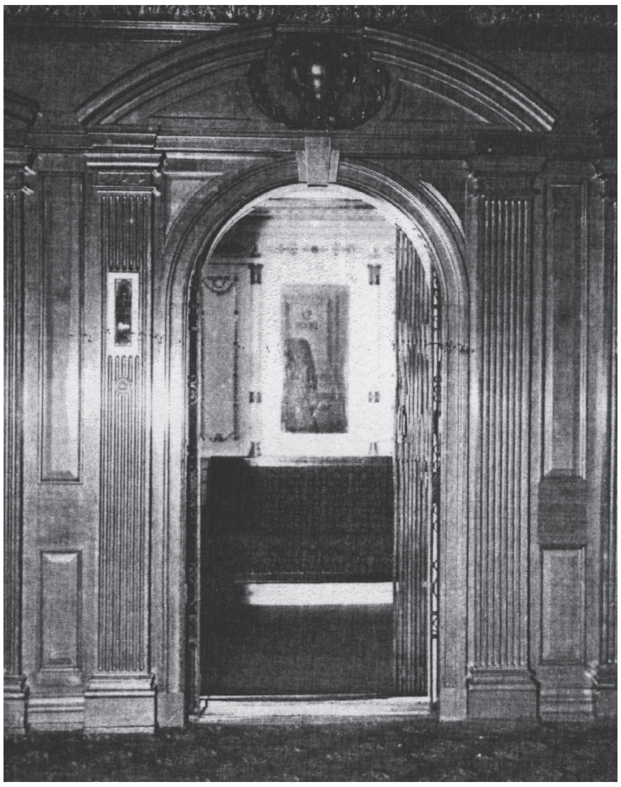


Fig. 17-66 **Elevator Cab on *Olympic*** – A view of the front of the center elevator cab on *Olympic*.

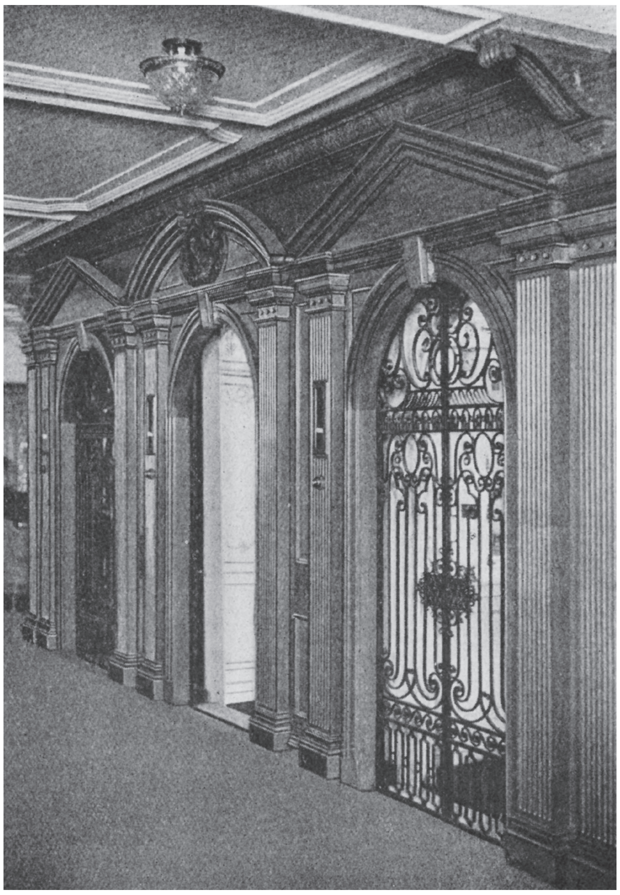


Fig. 17-65 **First Class Elevators on *Olympic*** – The First Class passenger elevators on what appears to be D Deck on *Olympic*. *(Daniel Klistorner collection)*

Second Class passengers were provided with one 15cwt lift traveling between the Boat Deck and F Deck. The cage was of mahogany,[17] fitted with an electric light and a Bostwick gate. The specifications of the winding gear and motor were the same as stated for the First Class elevators, except in this case, the capacity was only eight persons.

Titanic's elevators and service hoists were manufactured by R. Waygood & Co. Ltd of London. The winding gears were driven by four-pole, totally enclosed shunt-wound motors supplied by Laurence, Scott & Co. Ltd. A special safety gear was provided against breaking or excessive stretching of either of the suspension ropes fitted beneath the elevator cages. Each set of safety gear consisted of four steel fittings connected by suitable levers, and arranged to come

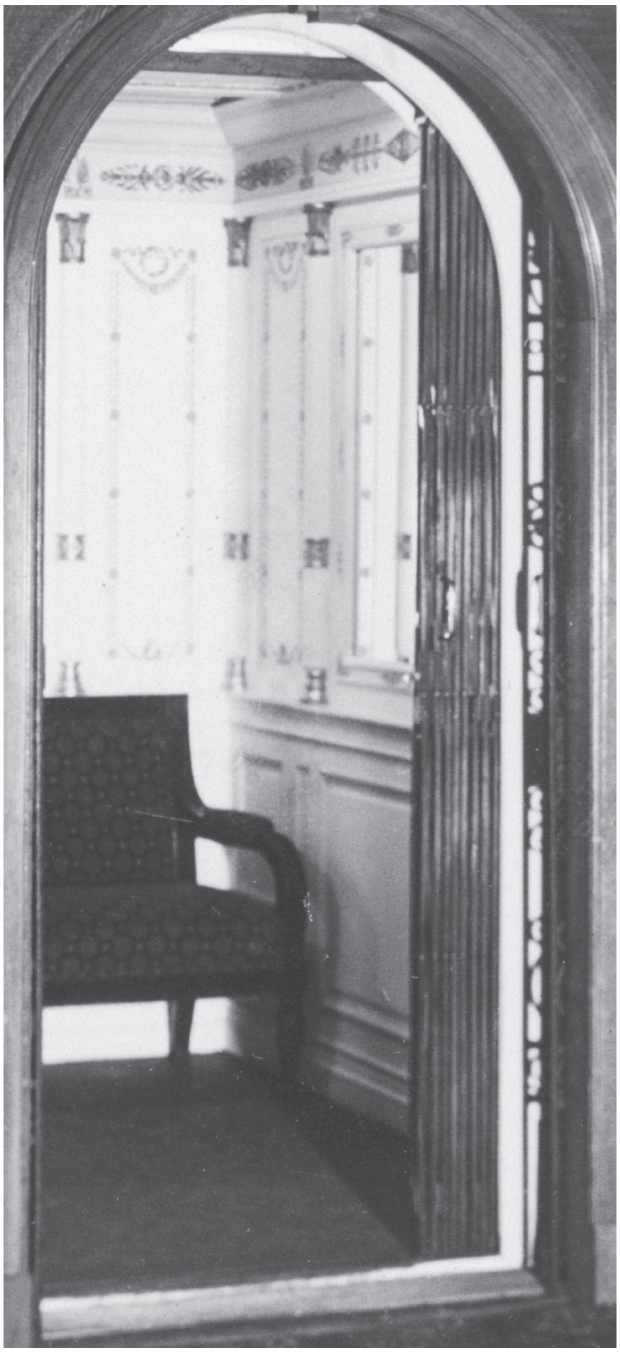


Fig. 17-67 **Details of Elevator Cab, *Olympic*** – Looking into one of *Olympic*'s elevator cabs.

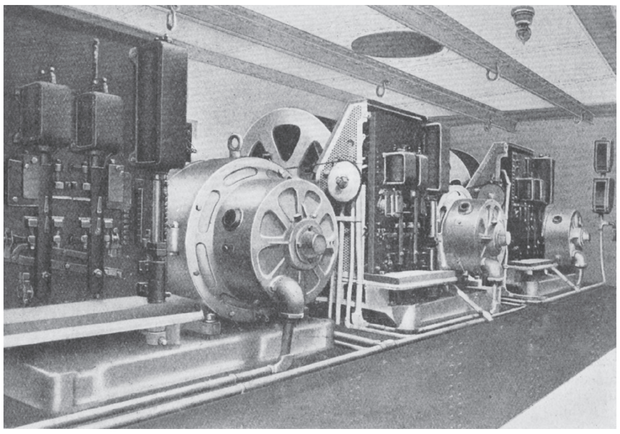


Fig. 17-68 **Elevator Motor Room** – The Elevator Motor Room of the First Class elevators on *Olympic. (Daniel Klistorner collection)*

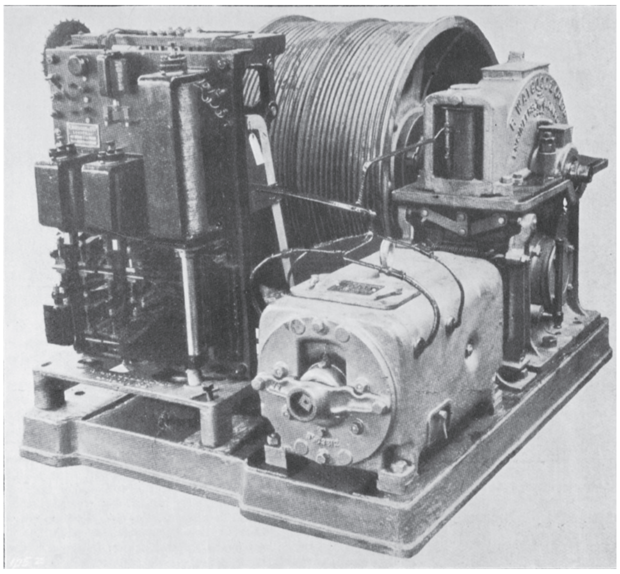


Fig. 17-69 **Elevator Motor Assembly on *Lusitania*** – This shows an elevator motor assembly from the *Lusitania*, which was also fitted with Waygood lifts. Though this motor assembly is smaller than the equipment installed aboard the *Olympic*-class liners, the components are generally the same. *(*Engineering*/ Authors' collection)*

into operation and grip the guides. This apparatus was activated by the opposing pull of ropes and did not depend on springs, but in the extremely improbable event of simultaneous failure of both suspension ropes, the safety gear would be brought into action by means of an independent safety line.

The guides for the cages and the counterbalances were of round turned steel, and each cage and weight was fitted with adjustable gunmetal guides to work against the steel runners.

The winding gear was fitted directly overhead on the Boat Deck, where the special slow-speed motors were fitted to ensure quiet running. The motors were rated at 6BHP when running at a speed of 500RPM, the rating being on the basis of a continuous six-hour run with full load and a rise of temperature not exceeding 70°F. They were coupled direct to machine-cut worm-and-wheel winding gear. The worms were made of solid steel, hardened and ground. The worm wheels were constructed with cast-iron centers with phosphor-bronze rims and teeth. The worm, being placed beneath the wheel, was enclosed in a cast-iron case forming an oil bath. The thrust of the worm shaft was taken by double ball thrust bearings, placed at the outer end of the worm shaft so as to be easily accessible for adjustment or repair.

The winding drum keyed to the worm wheel shaft was 3ft 6in in diameter, and arranged so that the two steel-wire ropes plumbed the center of the cage at one side, with two separate steel-wire ropes connected to the center of the counterbalance weight on the other side without any diverting sheaves. All high-speed shafts in the machine were brushed with gunmetal.

An automatic electric brake came into action when the current was shut off for any reason. The controller for electric operation was worked by a car switch in the cage, with a self-centering detachable handle. Special provision was made to guard against over-running in either direction in case of inattention on the part of the operator or any failure of the controller. A slack-cable safety switch was provided which would shut off the current and stop the running of the motor and gear if either the cage or counterbalance weight met with an obstruction on its journey, causing the ropes to become slack on the drum. This would also operate if the safety gear came into action owing to a failure of the suspension ropes. A main limit switch was also provided, operated by the travel of the cage, to shut off the main current in case of any failure or want of adjustment in the controller itself.

The counterbalance weight was equal to the weight of the cage and half the load, and safety angle guides were fitted at opposite corners of the cage to prevent it getting adrift in case it left the runners in the event of extreme rolling or pitching of the ship. In case of breakdown of the motor or failure of the current, a special attachment had been designed for raising or lowering the lift by hand.

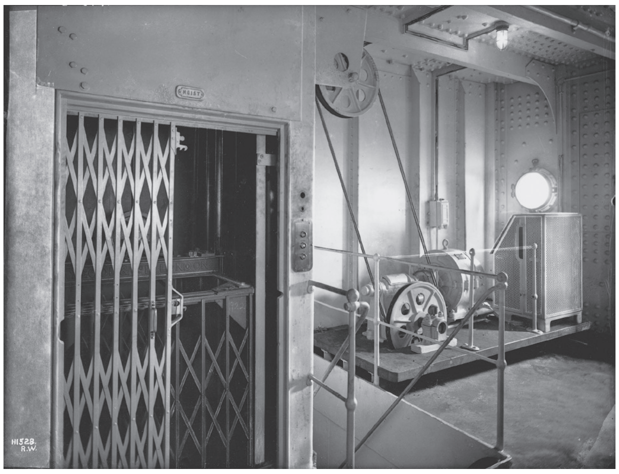


Fig. 17-70 **Service Hoist on *Olympic*** – One of *Olympic*'s service hoists. This one was located at the aft end of the galley facilities on D Deck, on the port side close to the Printer's Shop. *(H&W/Authors' collection)*

Service hoists

Electric service hoists about the ship were provided by the firm of Waygood & Co. and were fitted with motors manufactured by Laurence, Scott & Co. Ltd. These hoists were also provided with guides, ropes, and safety devices. Position indicators and speaking tubes were also fitted in connection with these hoists. With the exception of one hoist whose source of power is unknown, all were controlled by push buttons placed at each deck serviced. All of the lifts and elevators were fitted on board by the manufacturer.

Following are the locations, specifications as known, and areas serviced by the various service hoists on *Titanic*:

Service Hoist Specifications

Service hoist at frame 24A, starboard side:2BHP motor, 3cwt capacity, cage 1ft 7in by 2ft 2in by 2ft 6in

Boat Deck	Pantry adjoining Officers' Mess
A Deck	Lounge & Deck Pantry
B Deck	(trunked)
C Deck	Petty Officers' & Marconi Officers' Dining Saloon
D Deck	First and Second Class Galley Pantry

Service hoist between frames 49A and 50A, port side inboard: 2BHP motor, 3cwt capacity, cage 1ft 7in by 2ft 2in by 2ft 6in

B Deck	*à la carte* Restaurant Galley
C Deck	(trunked)
D Deck	First and Second Class Galley

Service hoist between frames 49A and 50A, port side outboard: unknown if electrically powered

D Deck	First and Second Class Galley
E Deck	Pantry adjoining Engineers' Mess

Service hoist between frames 69A and 71A, port side: 5BHP motor, 10cwt capacity

D Deck	Passageway accessing Second Class Pantry, First and Second Class Galley, Butchers' Shop and Bakers' Shop
E Deck	Passageway adjacent Potato Store and Potato Wash Place
F Deck	(trunked)
G Deck	Stores area forward, adjacent Flour Room
Orlop Deck	Stores area forward

In the case of the hoist between the Post Office and Mail Room, the headroom for the motor was very limited, so the cage was arranged with multiplying sheaves underneath giving a mechanical advantage of two to one, and the counterbalance weight was also fitted with multiplying sheaves.

Kilroy's Stoking Indicators

The advantages of careful, systematic, and regular firing in steam boilers were well known to Engineers, especially where fuel economy and the prevention of smoke were important, and any arrangement or method that could assist the Engineer in charge in realizing these aims was highly desirable. This was particularly so in the stokeholds of steamships, where it so often happened that a number of boilers were worked in connection with one another. There were few seagoing Engineers in 1912 who were unaware of the dangers of relying too much on the intelligence of the stoker for the regular firing of furnaces at fixed times. Any mechanical appliance that could relieve the Engineers of this area of their responsibilities was surely welcome, particularly so if the appliance could be relied upon to fulfill its duties in a consistent and unfailing manner. In addition, by *Titanic*'s time, boilers in large ships had evolved to be of the double-ended type, with a common combustion chamber located between furnaces on each side. If the furnace doors on each side were opened simultaneously, the volume of air admitted would be too great and result in an undesirable drop in temperature. For this reason as well, it was desirable to employ some sort of indicator to prevent the simultaneous opening of the doors on each side, since the opposite ends of a double-ended boiler were located in entirely separate stokeholds out of visual communication with each other.

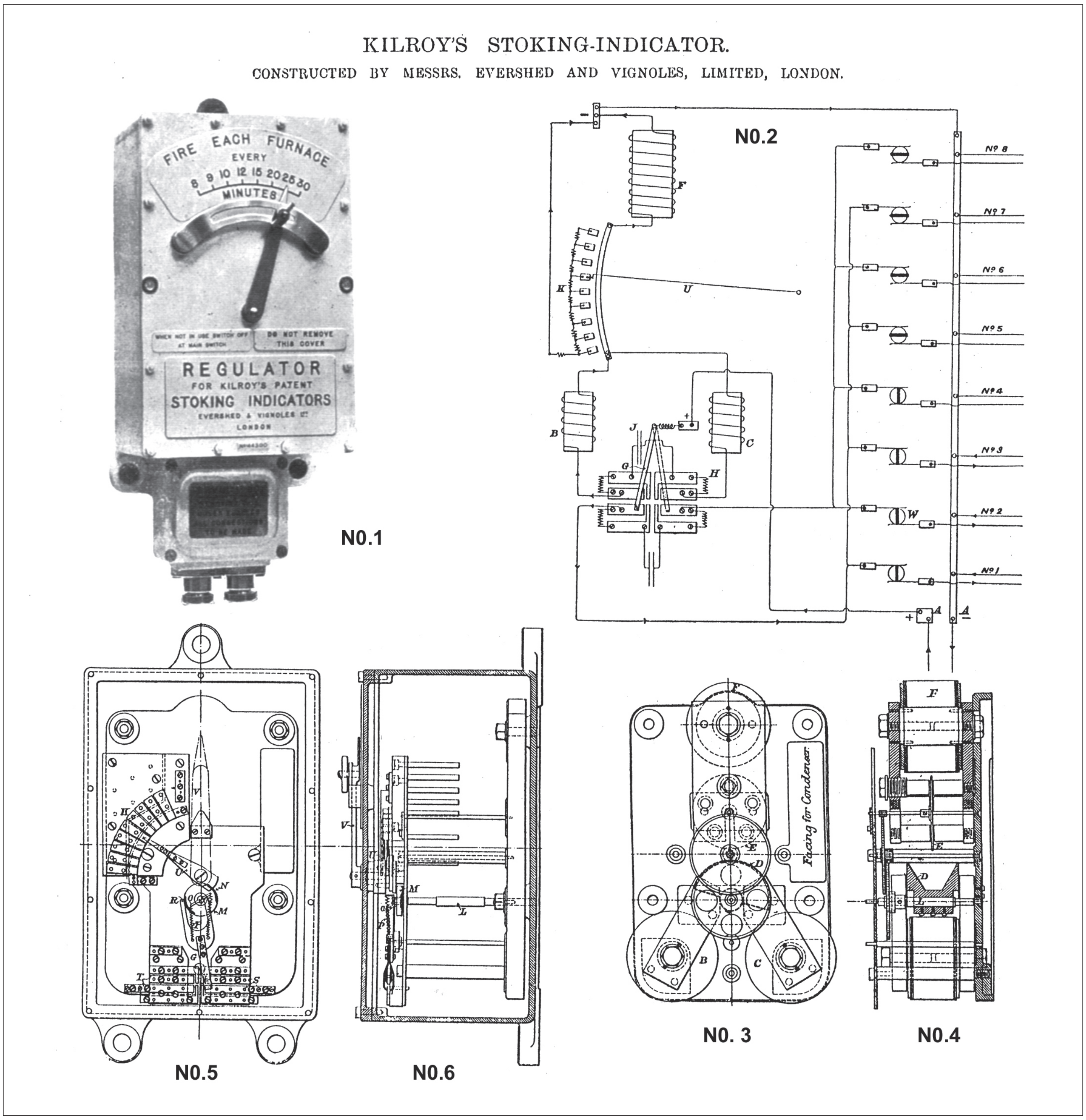
With these objects in mind, the 'Kilroy's Stoking Indicator' had been designed and patented. The system utilized a number of stoking indicators (a minimum of one for each stokehold or row of boilers), each of which rang a loud gong and displayed the number of the furnace to be fired. This sequence occurred at regular intervals of time and in definite rotation, all the indicators being actuated electrically by one regulator, or timing apparatus, which was placed in the Engine Room. It was, of course, essential that each boiler furnace be numbered, preferably with brass numbers, because painted or chalked numbers were apt to be obliterated.

At the Starting Platform in the Engine Room, the Engineer on watch would set his transmitter to the interval at which he wanted each furnace to be fired – i.e., every eight minutes, ten minutes, etc. In each boiler room, the bell on the indicator would ring at the required interval, and display the number of the furnace to be fired. This merciless repetition, which continued without pause, ensured the most efficient firing of all the boilers operating together. When one considers that on *Titanic* the forward-most boiler room was over 300ft from the Engine Room, with 159 furnaces in the system across 29 boilers in six boiler rooms, the need for such coordination is readily apparent.

The regulator, or timing apparatus, consisted of a special switch mechanism, which at uniformly occurring intervals of time closed electric circuits and actuated the stokehold indicators. The arrangement of the switch mechanism was such that the stokehold indicators did not all ring at the same time. This was in order to avoid the opening of more then one furnace door at a time in any group of boilers.

On reference to Fig. 17-70, which shows the regulator situated in the Engine Room, it will be seen that a lever was provided to enable the Engineer to vary the rate of firing; for instance, with this particular model of the apparatus, if the regulator was set to an eight minutes' interval, and supposing there were eight furnaces in the stokehold, the indicator would show a new number and ring a bell every minute. By this means a complete rotation across all furnaces in the stokehold would be obtained over eight minutes. In order that only those indicators which were required would be placed in gear, a set of switches was provided, one for each indicator. The apparatus was strongly made and was watertight, and once switched into gear it was automatically operated and required no attention.

The general electrical principals for the Kilroy's Stoking Indicator are shown in No.5. An electric current from any convenient source, such as a lighting


KILROY'S STOKING-INDICATOR.
CONSTRUCTED BY MESSRS. EVERSHED AND VIGNOLES, LIMITED, LONDON.
FIRE EACH FURNACE
EVERY
8 9 10 12 15 20 25 30
MINUTES
WHEN NOT IN USE SWITCH OFF AT MAIN SWITCH
DO NOT REMOVE THIS COVER
REGULATOR
FOR KILROY'S PATENT
STOKING INDICATORS
EVERSHED & VIGNOLES LTD
LONDON
N0.1
N0.2
Nº 8
Nº 7
Nº 6
Nº 5
Nº 4
Nº 3
Nº 2
Nº 1
F
K
U
B
C
J
G
H
W
A
A
Facing for Condenser
E
D
B
C
N0. 3
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E
D
L
N0.4
V
K
U
N
M
R
T
S
N0.5
V
M
L
P
N0.6

Fig. 17-71 **Kilroy's Stoking Indicator (1)** – A schematic diagram and photograph of the transmitter, located in the Reciprocating Engine Room. By means of this mechanism the engineer on watch would set the time interval at which he desired the individual furnaces to be fired. *(*Engineering*/Authors' collection)*

circuit, was carried from the terminals A to either of the driving electromagnets B and C, Nos 2 and 3. These electromagnets acted upon a pivoted soft iron armature D, Nos 3 and 4, which communicated with its motion through gear wheels to the plane copper disc E. This disc, rotating as it did in the field of another electromagnet F, acted as a Foucault brake. This magnet could, for the sake of convenience, be called the brake magnet.

The windings of the brake magnet and those of the driving magnet were arranged in series, in order that the relation between the pull exerted on the armature by the driving magnet, and the driving force on the copper disc, due to the field of the brake magnet, would remain practically constant with changes of voltage.

The two driving magnets B and C were arranged symmetrically about the axis of the soft iron armature, but only one of them was energized at a time. An automatic switch G (Nos 2 and 5), depending for its action on the motion of the armature D, served to break the circuit of one magnet and make the circuit of the other when the armature moved in one direction or the other to the end of its swing. This motion of the armature first one way and then the other, and the consequent movement of the brake disc in like manner, was continuous and automatic

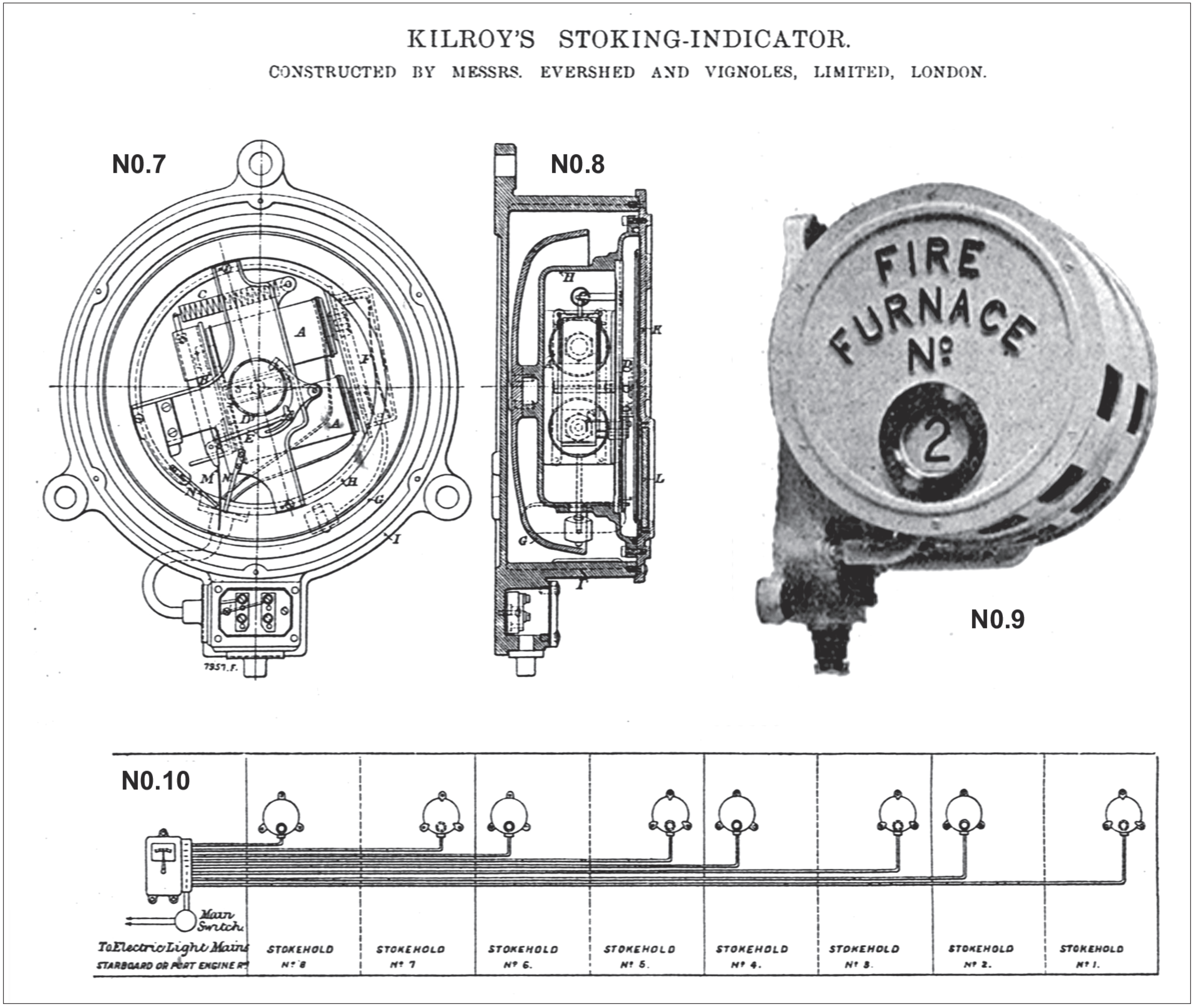

KILROY'S STOKING-INDICATOR.
CONSTRUCTED BY MESSRS. EVERSHED AND VIGNOLES, LIMITED, LONDON.
N0.7
N0.8
FIRE FURNACE Nº
2
N0.9
N0.10
Main Switch
To Electric Light Mains
STARBOARD OR PORT ENGINE Rm
STOKEHOLD Nº 8
STOKEHOLD Nº 7
STOKEHOLD Nº 6.
STOKEHOLD Nº 5.
STOKEHOLD Nº 4.
STOKEHOLD Nº 3.
STOKEHOLD Nº 2.
STOKEHOLD Nº 1.

Fig. 17-72 **Kilroy's Stoking Indicator (2)** – A diagram and photograph of an individual stoking indicator. These units were mounted in the various stokeholds, and sounded a gong as well as indicating the furnace to be fired. The bottom diagram illustrates the arrangement of the transmitter and the receivers throughout the ship. *(*Engineering*/Authors' collection)*

so long as the apparatus was switched onto the supply current. The automatic switch G in the regulator, besides directing the current to the driving magnets, made and broke the necessary contacts required to bring the indicators in the stokeholds into action. Resistances H and condensers J (No.2), in connection with the contact of the switch, were used to reduce the spark in the breaking of the inductive circuits. The electro-brake magnet was provided with a subdivided shunt resistance K (Nos 2 and 5) which could be operated from the outside, and served as a means of altering at will the speed of the mechanism, and therefore the rate of the firing up of the furnaces. This shunt resistance was wound with nickel wire on account of its high temperature coefficient of resistance, and it formed a means of compensating for the temperature coefficient of the copper brake disk, so that the timing was practically unaffected by changes of temperature.

The connection between the armature D and the current-driving switch G will, perhaps, be better understood by further reference to Nos 5 and 6. Upon the spindle L of the armature D a small disk M was mounted, having at its periphery a discontinuous guard flange N in two parts, and also an arm piece O, which oscillated with armature D, Nos 3 and 4. To the ends of the arm piece O were fixed two spiral springs P, connected at their other ends to two points, one on each side of the axis of the switch G. The upper end of the switch terminated in a fork, as shown in No.5. This fork was itself clear of the disc M and the guard flanges N, but each end of the fork had a projecting pin R, which engaged against the outside of one of the flange guards N when the switch G was at the end of its travel.

When the armature had completed part of its oscillatory travel between the poles of the magnets, the springs P tended to make the switch G pass over to its other oblique position, but one of the projecting pins R, resting on the guard flange N, prevented its movement until the flange had completed its oscillatory movement. The tension of one of the springs P then brought over the switch arm G suddenly, thus sharply breaking and re-making the alternative contacts S and T, No.5, the armature would then be attracted by the other driving magnet, and so put into circuit. It will be seen also on reference to No.2 that the action of the switch broke the circuit in the one set of indicators, and closed the circuit to the other set.

Referring again to Nos 5 and 6, it will be seen that the arm U had its spindle carried through the watertight casing to an external pointer, which could be moved to and fixed in any desired position on the scale shown in No.1, thereby determining the intervals between the stoking of each furnace.

Turning now to the stokehold indicator, it will be seen on reference to Figure 63, Nos 7 and 8, that this consisted of an operative magnet A which was energized by the current through the time regulator. The electromagnet attracted an inner pivoted armature B against the reaction of a spring C, and this armature during its motion operated a disc D by means of a pawl E.

The disc carried a series of numbers indicating particular furnaces in any boiler or group of boilers, and these numbers were displayed through an aperture in the outer casing of the indicator. At the moment any new number was displayed another armature F was attracted to the other poles of the magnet, and actuated a striker on the bell G, and gave audible notice of the change of number.

The operative electrical mechanism was enclosed in a watertight casing shown at H, the whole apparatus being encased in a protective cover I, which was provided with perforations in its lower part to enable the sound of the bell to be easily heard. The cover K of the outer casing had in it a glass window L, through which the numbers could be read.

The pawl E, which was pivoted to one end of the armature B, was controlled by a tail spring M, which came alternately against the stops N, and thereby inserted or withdrew the pawl from the perforated wheel D.

Switches W, No.2, were introduced to cut out any indicator when it was not in use. No.9 is a perspective view of one of the stoking indicators.

Notes

1. This space was also referred to as the Generator Room or Dynamo Room.
2. The *Olympic*-class ships were among the first ships where the use of electricity had grown to a point where the machinery required a dedicated compartment; in fact, Harland & Wolff was forward-thinking enough that it actually built foundations into the double bottom to support two *additional* 400-KW machines in the shaft tunnel abaft the Electric Engine Room, should they be required in the future.
3. 'Parallel' meant that the output of two or more generating sets was combined such that the amperage increased while the voltage remained the same, or in other words, combining their output to handle an increased electrical load.
4. Micanite was manufactured from the mineral mica, ground and pressed into sheets.
5. *Titanic* would have been supplied with red emergency oil lamps in case all of the generating sets went down, but these would be stored and not used regularly like on earlier vessels.
6. Survivors reported that *Titanic*'s lights dimmed shortly before the ship broke apart amidships and sank. It is very likely that the dim lighting seen in her final moments was the emergency lighting provided by the emergency dynamos.
7. These were the two huge ducts that flanked the after end of the Second Class Entrance on the Boat Deck. While primarily serving as ventilation trunks, they were also utilized to run the cables up from the feeder switchboard before they branched out to other areas of the ship.
8. SWG is an abbreviation for Standard Wire Gauge [Imperial or British]; numbers such as '61/12' indicate a stranded conductor, where the first number indicates the number of strands and the second number indicates the 'gauge' or thickness of the individual strands. Therefore, '61/12' indicates a conductor made of 61 strands of 12 SWG solid copper wire which, per the standard, had a diameter of 0.104 in. [2.64 mm].
9. 'Sidelights' in context refers to the navigation lights fitted to the outboard sides of the Bridge wing cabs. These should not be confused with sidelights that provide light and ventilation to interior spaces. The navigation lights themselves are described in detail in the chapter covering navigational equipment.
10. In period write-ups such as *The Electrician* and *The Shipbuilder,* the term 'lamp' was frequently used in reference to an incandescent bulb with a filament as well the fixture in which it was held. To avoid

confusing the two, in this text 'light bulb' has been used in reference to the source of illumination.

11. The most common candlepower rating for cargo clusters, cabins and general use aboard ship was 16. Candlepower is not the same as wattage; it is a measure of radiance – a rating of light output at the source.
12. The term 'majolica' normally refers to a type of pottery decorated with bright colors and a heavy, opaque glaze. While majolica lamps did exist in 1912, there is no evidence of their being used on the *Olympic*-class ships as they do not appear in any of the numerous stateroom images available. The term 'majolica,' in referring to the light fixtures on these ships, was apparently used broadly to refer to any ceramic material with a semi-translucent glaze.
13. It should be noted that 'pendant light' was nothing more than a general term for a downward-hanging light. Some sconces had downward-hanging lamps, for example, and these individual lamps within the fixture were also termed pendant lights.
14. The original writings on the telephones indicates fittings for a number of First Class staterooms. However, this seems to be merely an early plan as no telephones are visible in any photographs of *Olympic*'s or *Titanic*'s staterooms. The most likely locations for telephones within passenger accommodations would have been the four Parlor Suites. However, some of these were photographed extensively and none reveal evidence of a telephone. This does not preclude the possibility of them being hidden behind a panel or fitted in some other location out of view, but more likely, they were never fitted.
15. These locations have been taken from Harland & Wolff's Drawing Office notebook.
16. It must be remembered that the First and Second Class Galley was one large facility serving the Dining Saloons for both classes.
17. *Titanic* survivor Eva Hart stated that her father told her the wood was of 'bird's-eye maple.' There is no way to verify this; however, bird's-eye maple was not known to be used aboard *Olympic* or *Titanic*. *Olympic*'s auction book specifies that her Second Class elevator cage was of mahogany and one could easily assume the same would be the case for her sister.

Chapter 18

Refrigeration and Insulation

All large ocean-going passenger steamers were provided with refrigerating machinery and insulated chambers for carrying fresh meat for consumption during the voyage; many steamers were also equipped to carry cargoes of frozen or chilled meat. *Titanic* carried a large array of food and perishables, all requiring refrigeration at various temperatures in separate compartments: fruit, flowers, fish, mutton, eggs, butter and poultry, to name just a few. Some of these were required in large quantities: the amount of butter alone was 6,000lb, and the amount of beef totaled 75,000lb. *Titanic* was fitted with freezers for both east-bound and west-bound beef, both freezers sharing a separate and adjoining Thawing Room. This was indicative of the huge amount of food that was carried and the concern over freshness.

The holds and store rooms devoted to this purpose were insulated and, depending on requirements, were kept merely cooled or at freezing or near-freezing temperatures throughout the voyage. *Titanic*'s refrigerating equipment was designed to the White Star Line's specifications and not only provided for the cooling of the ship's provision rooms and pantry larders, but also cooled drinking water supplied to cupboard coolers and various points throughout the First, Second and Third Class accommodations. Space was also provided for refrigerated cargo at the aft end of the Orlop Deck, with a capacity providing for about 40 cubic ft per ton.

The degree of refrigeration required depended on the cargo. For instance, mutton was shipped in whole carcasses which were frozen before shipment and had to be kept so throughout the voyage. The carcasses were stowed one on top of another and, being hollow and quite hard, the spaces in and around them provided for a proper circulation of air. The temperature of the store room for frozen mutton was usually about 15°F. Frozen mutton suffered little to no harm from being kept in a frozen state, although it tended to gradually become dry and less juicy.

The stores of beef were maintained at a temperature just above the freezing point, and were termed 'chilled beef'. It kept well for several weeks and was actually in better condition for use after than before the voyage. The successful carriage of chilled beef required much greater care than that of frozen mutton, as the temperature of the hold had to be kept at a uniform temperature throughout so that the beef would not freeze. To accomplish this, the refrigerating apparatus was refined with a view toward precision regulation of the temperature of the brine coils, or 'grids', which were necessarily numerous and extensive in order to provide ample cooling in every part of the compartment.

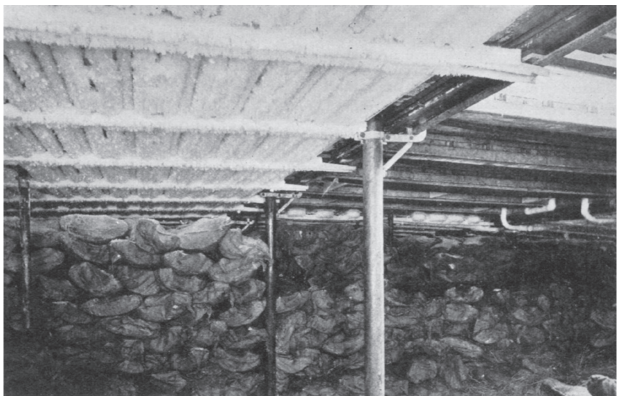


Fig. 18-1 **Cargo Space for Frozen Meat** – Cargo space for frozen meat in a ship of *Titanic*'s era.

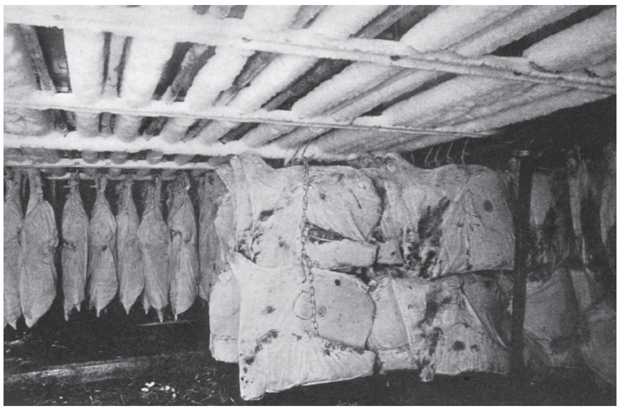
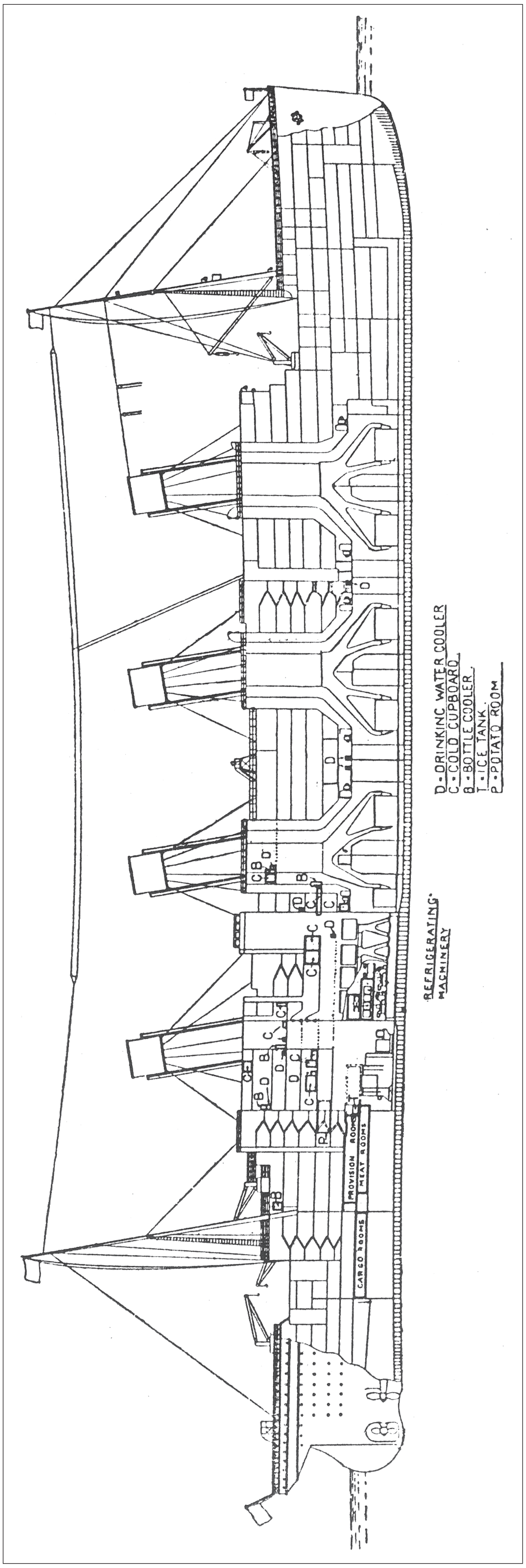


Fig. 18-2 **Cargo Space for Chilled Meat** – Cargo space for chilled meat in a ship of the era. Notice that the pieces are hung rather then stacked.



Chilled beef was usually shipped in quarters which, being soft, could not (like frozen mutton) be stowed one piece on top of another. It was, instead, suspended from the deck above by chains and hooks. The quarters were suspended in such a way that the cold air of the hold could circulate around each piece but with the quarters close enough so that the hold could be properly filled. This also served to restrict any swinging of the suspended meat induced by the movement of the vessel. It should be noted that the weight of a cargo of chilled beef, stowed in the hold in this way, fell entirely on the deck from which it was suspended instead of being distributed on the bottom of the hold and this had to be taken into account when constructing these spaces.

Refrigeration machinery

The refrigeration units were of the 'CO_2' type, utilizing this gas (carbon dioxide) in its compressed form instead of air. The CO_2 liquefied when cooled, at which point it was passed through a coil of iron piping located within a tank containing brine (a solution of chloride of calcium). Within this coil the CO_2 absorbed heat from the brine, expanded and reassumed its gaseous form at about -10°F. The surrounding brine became quickly chilled in turn and, when reduced to about 0°F, was withdrawn by a pump and circulated through the circuits or 'grids' of piping that ran under the decks and along the upper parts of the vessel's sides to the refrigerated compartments. Separate grid sections within each compartment were interlaced so that if one part were to fail, it would not cause a loss of cooling to an entire wall or ceiling. Grid sections were fastened in place with hanger bolts and angle-iron supports and were not to exceed approximately 1,200ft each in length.

Although carbon dioxide gas had drawbacks, its major advantage was a greater degree of safety in case of a leak. Carbon dioxide gas is a respirable gas, and although the escape of a large quantity could certainly be dangerous, in small amounts it did not present a significant hazard. On the other hand, being odorless, leaks were not readily detected.

Titanic's refrigeration system was manufactured by J. & E. Hall Ltd, Kent, and consisted of two horizontal duplex machines, each of which combined two complete units

Fig. 18-3 **Drawing of Refrigeration Outfit on *Olympic*** – This is an original period illustration, as evident by the distortion caused by multiple copies over many years. It depicts the location of *Olympic*'s refrigeration equipment. Although very simplistic, it does give an orientation as to where these refrigeration fittings were located. Note the cold cupboard in the No.4 Funnel deckhouse on the Boat Deck. This arrangement appears in early general arrangement plans of *Olympic*, but apparently never came to pass.

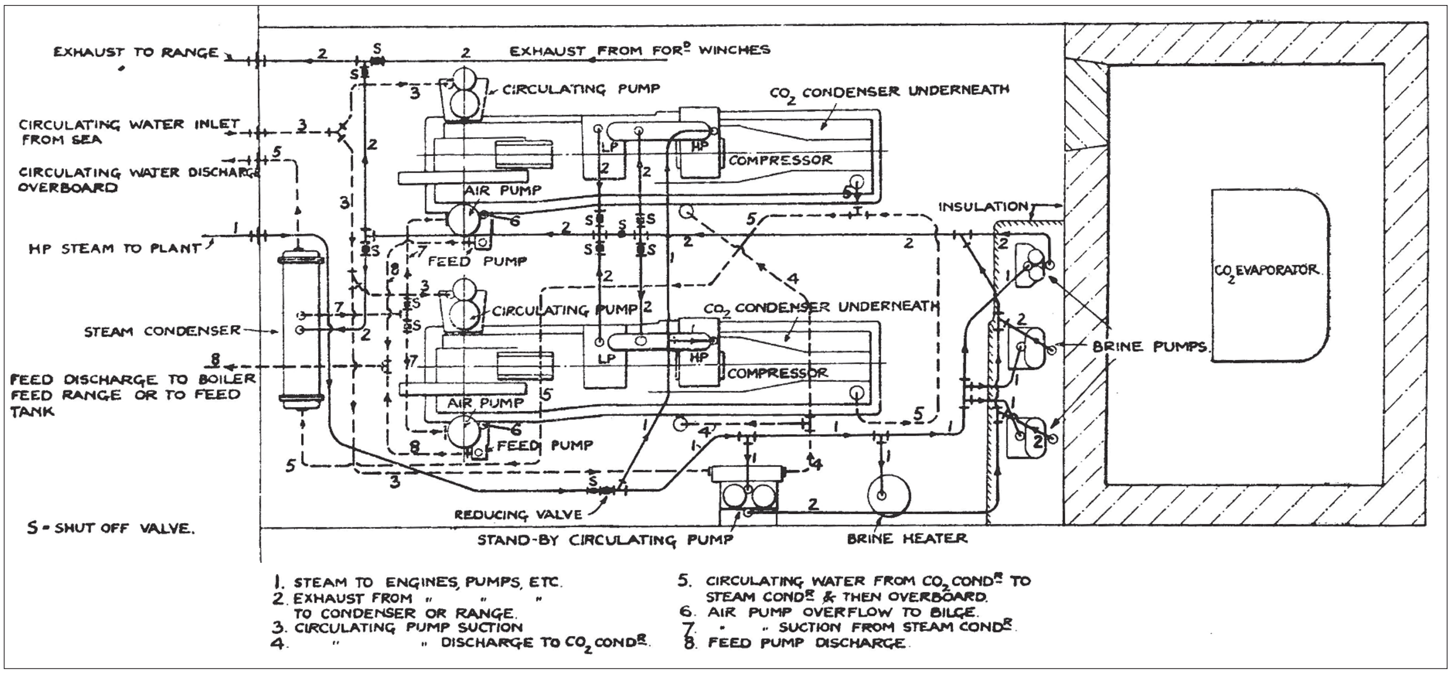

EXHAUST TO RANGE
EXHAUST FROM FOR^D WINCHES
CIRCULATING PUMP
CO2 CONDENSER UNDERNEATH
CIRCULATING WATER INLET FROM SEA
CIRCULATING WATER DISCHARGE OVERBOARD
LP
HP
COMPRESSOR
AIR PUMP
INSULATION
HP STEAM TO PLANT
FEED PUMP
CO2 EVAPORATOR
STEAM CONDENSER
BRINE PUMPS
FEED DISCHARGE TO BOILER FEED RANGE OR TO FEED TANK
REDUCING VALVE
S = SHUT OFF VALVE.
STAND-BY CIRCULATING PUMP
BRINE HEATER
1. STEAM TO ENGINES, PUMPS, ETC.
2. EXHAUST FROM " " " TO CONDENSER OR RANGE.
3. CIRCULATING PUMP SUCTION
4. " " DISCHARGE TO CO2 COND^R.
5. CIRCULATING WATER FROM CO2 COND^R TO STEAM COND^R & THEN OVERBOARD.
6. AIR PUMP OVERFLOW TO BILGE.
7. " " SUCTION FROM STEAM COND^R.
8. FEED PUMP DISCHARGE.

Fig. 18-4 **General Refrigeration Fittings** – This schematic diagram shows a Hall's refrigeration plant designed and installed aboard a Harland & Wolff-built steamer. All of the basic equipment and connections shown here were present in the much larger installation fitted aboard *Titanic*, although the equipment differed in certain details, was spread out over a greater area and occupied space on several decks. In this diagram, two refrigerating engines of the simplex type are shown, whereas each of the machines on *Titanic* were of the duplex type. A common surface steam condenser is indicated for each machine in the diagram, while each of the duplex machines on *Titanic* had its own independent steam condenser. A single evaporator is shown here, while *Titanic* had two duplex evaporators for a total of four, and these, along with the brine pumps, were located remotely from the refrigeration engines. Note that this diagram only deals with the steam supply, return feed and steam condenser circuits of the installation – those portions which the shipyard engineers would have been responsible for – and not the brine circulation and return system, which was entirely the responsibility of the refrigeration plant contractor.

capable of independent operation, so that actually four refrigerating units were provided. Half of the refrigerating installation had ample capacity to deal with the whole of the duties required; the other half were considered reserves. These machines were located on the port side of the Reciprocating Engine Room. The compressors were bored from solid blocks of high-carbon steel and the condenser coils, of solid drawn copper, were contained in the compressor bases, each of which was divided into two castings. Each machine had its own steam surface-condenser, brass circulating pump, and air and feed pumps. A duplex brass-ended water pump was also provided as a standby. The evaporators were correspondingly divided into four complete nests of coils contained in two D-shaped casings. These were placed in an insulated recess above at the Orlop Deck level, directly above the refrigeration machines and near the three interchangeably connected brine pumps located in an adjacent room. The brine pumps were designed to be used for either high or low pressure for effecting the circulation throughout the ship. The brine return tank was placed immediately above the evaporators, to which all the returns from the refrigerated cargo hold and store rooms, ice tanks, water coolers and cupboard coolers could be led. The brine flowed from the tank by gravity to the evaporators, from

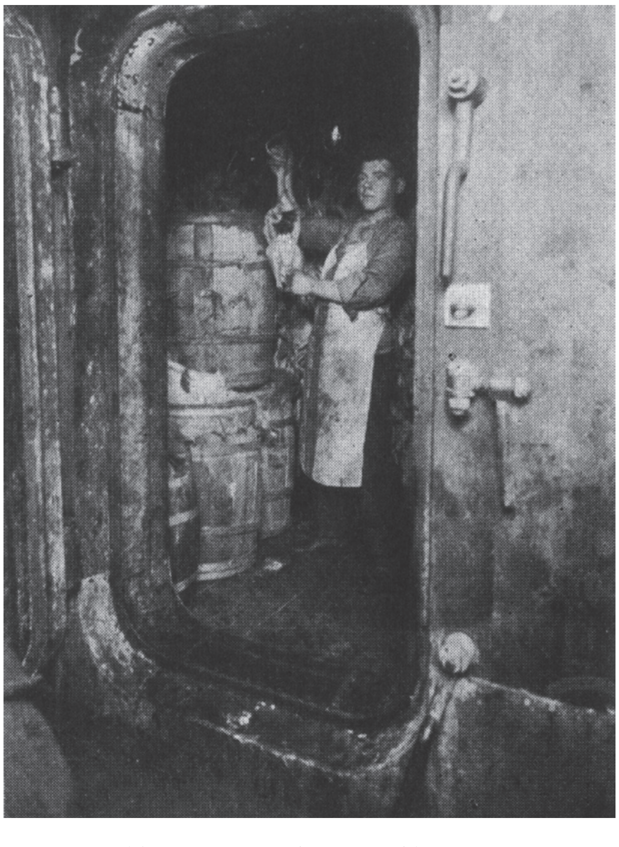
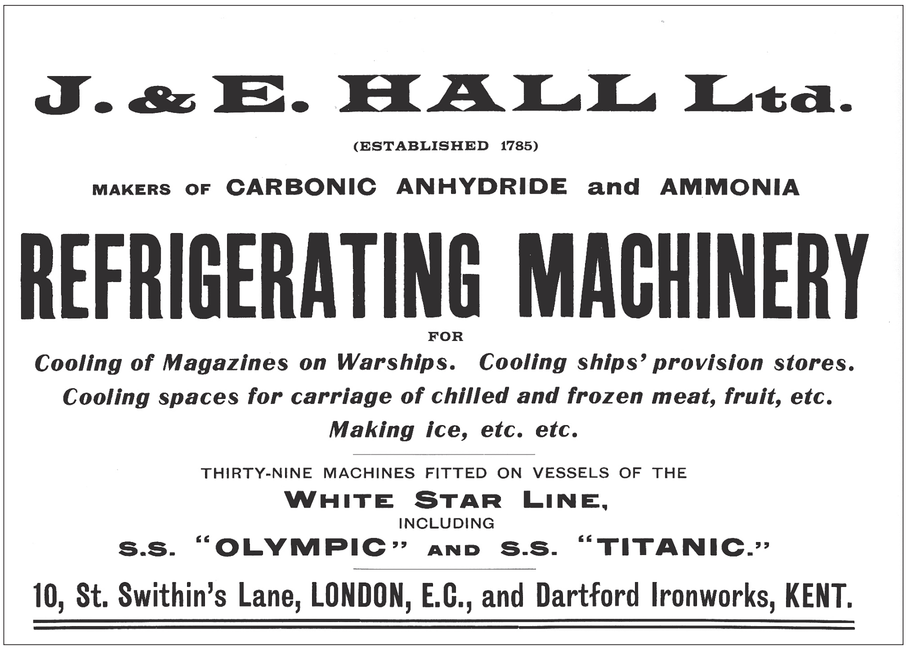


Fig. 18-5 **Cold Storage** – Poultry in a cold storage room aboard an ocean liner *c.*1912. This image is believed to be from a German ship. *(J. Kent Layton collection)*



J. & E. HALL Ltd.

(ESTABLISHED 1785)

MAKERS OF CARBONIC ANHYDRIDE and AMMONIA

REFRIGERATING MACHINERY

FOR

Cooling of Magazines on Warships. Cooling ships' provision stores.
Cooling spaces for carriage of chilled and frozen meat, fruit, etc.
Making ice, etc. etc.

THIRTY-NINE MACHINES FITTED ON VESSELS OF THE
WHITE STAR LINE,
INCLUDING
S.S. "OLYMPIC" AND S.S. "TITANIC."

10, St. Swithin's Lane, LONDON, E.C., and Dartford Ironworks, KENT.

Fig. 18-6 **Advertisement for J. & E. Hall Refrigeration Machinery**. *(*The Shipbuilder*/Authors' collection)*

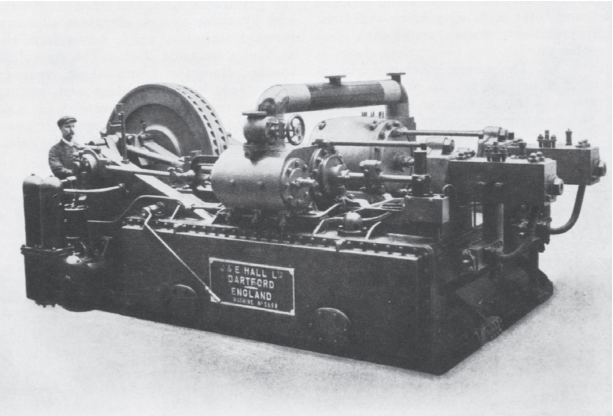


Fig. 18-7 **J. & E. Hall Refrigeration Engine**. *(*The Shipbuilder*/Authors' collection)*

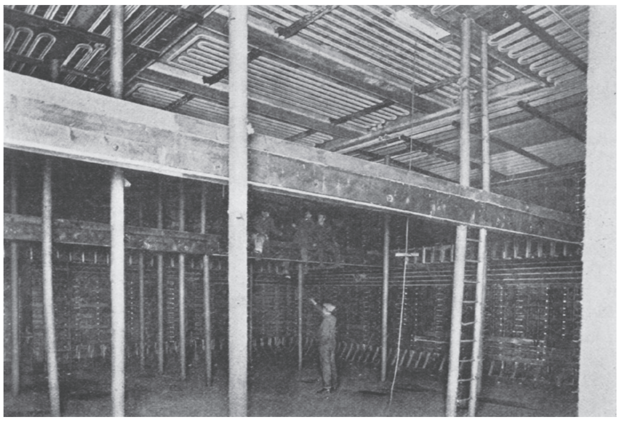


Fig. 18-8 **Arrangement of Brine Piping in Hold** – Arrangement of brine piping in a refrigerated hold of a cargo ship of *Titanic*'s era.

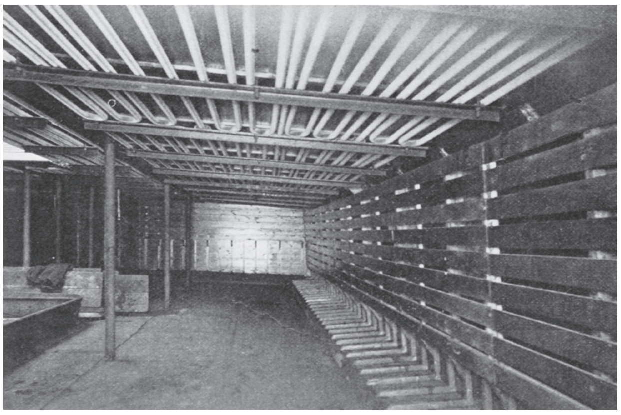


Fig. 18-9 **Brine Pipes and Grating in 'Tween Decks Cargo Space** – Typical arrangement of brine piping in the 'tween deck area of a cargo ship of the era.

which the pumps delivered it to the distribution boxes in the handling room and then via separate delivery pipes to the various refrigerated compartments, each delivery pipe being fitted with a shut-off cock and each return being fitted to a stop valve, brass thermometer and return fittings. A main brine pipe was taken from the refrigeration engine to serve both the water and cupboard coolers about the ship, and another main brine delivery was specifically taken to the refrigerated cargo hold and stores area to a distribution box having delivery and cocks to each section.

The brine circulation was on the open return system, with separate flow and return on each circuit. All brine pipes were electrically welded, externally galvanized and of 1¾in bore by 6in gauge. The sections were of moderate length, not exceeding 1,200ft, and, as noted, were interlaced in the various compartments to ensure even distribution of the cooling effect even in the remote chance of one section becoming blocked. The grids were arranged both overhead and on the sides as required.

Water coolers

The water coolers each consisted of a circular galvanized-steel casing fitted with a removable cover and an externally galvanized brine coil. Each was fitted with a bypass and a valve on the brine circulation, with a suitable brass draw-off cock. Each cupboard cooler was fitted with galvanized pipes externally similar to those of the water coolers, with shut-off cocks or valves as required by their specifications.

Ice-making machines

Titanic had two ice-making machines located in a room in the Stores area on G Deck, with an adjacent Ice Room that was insulated and refrigerated. Each ice-making machine was fitted with 12 galvanized steel molds or 'tanks' capable of making blocks of ice weighing 47½lb. An ice 'rocker' with a totally enclosed electric motor of 7½BHP was also provided for breaking the large blocks produced in the tanks into small pieces. The tanks were lagged with washed cow hair 3in thick, retained by 1in-thick pine matchboard strapped together by wrought-iron bands. The ice machine operated by extracting heat from brine through the expansion of the CO_2 on the same principle as the refrigeration machinery. Since the brine froze at a temperature considerably below the freezing point of fresh water, it could be used to make ice.

Insulation

With regard to refrigerated holds and store rooms on a ship, insulation could be described as the covering of the exposed steelwork of the hull with a thick layer of non-conducting material so that nowhere would the cold air of the hold come in contact with it. Since steel is a conductor and is warmed by the outside air and sea water, it could rapidly extract and dissipate the cold within the refrigerated compartments. The thoroughness of the insulation, or, in other words, the thickness and continuity of the layer of non-conducting material was paramount to its effectiveness. Once the hold and the cargo were chilled to the required temperature, if the hold were well-insulated both it and cargo within would remain at that temperature with little necessity for further refrigeration and minimal risk of the local warming that sometimes occurred through imperfections in the insulation. When insulation was imperfect, the temperature tended constantly to rise; to keep it down required the nearly continuous running of the refrigerating engine with danger to the cargo due to variations of temperature. Furthermore, with a cargo of meat, if the temperature rose enough at any time to the point where the meat began to thaw, it would be seriously damaged. It was rare, however, that this happened, except locally under the hatches or where the insulation had become defective, or in corners under projecting stringers or deck girders where the circulation of cold air had been impeded and had not penetrated. Frequently, the cause of spoilage was not due to any defect in the refrigeration. In many cases, the carcasses of meat were shipped soft and became so crushed together as to prevent the cold air from circulating between them. (This particular problem was most likely to happen with carcasses placed lower in a deep hold.)

The insulating material commonly employed on the ships like *Titanic* was granulated cork.[1] Cork had the advantage that should any of it leak through the wood lining and settle on the meat, it would do little or no

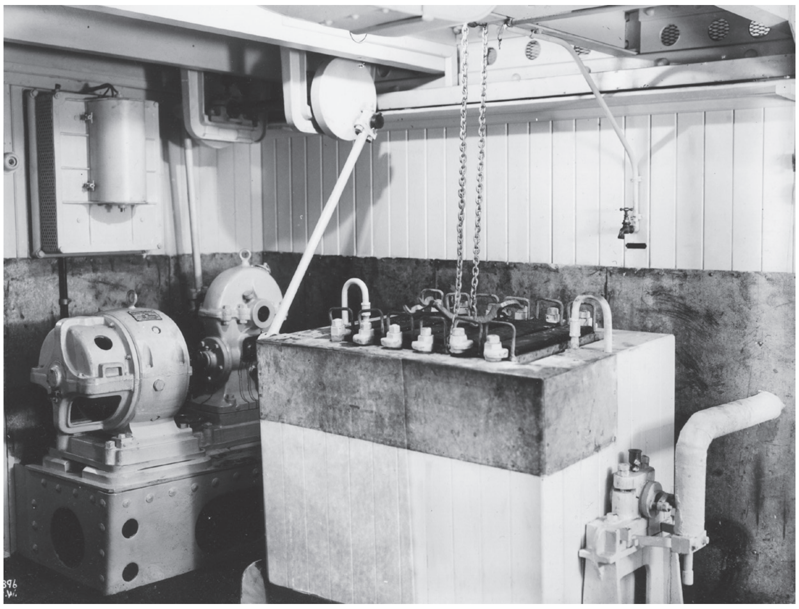
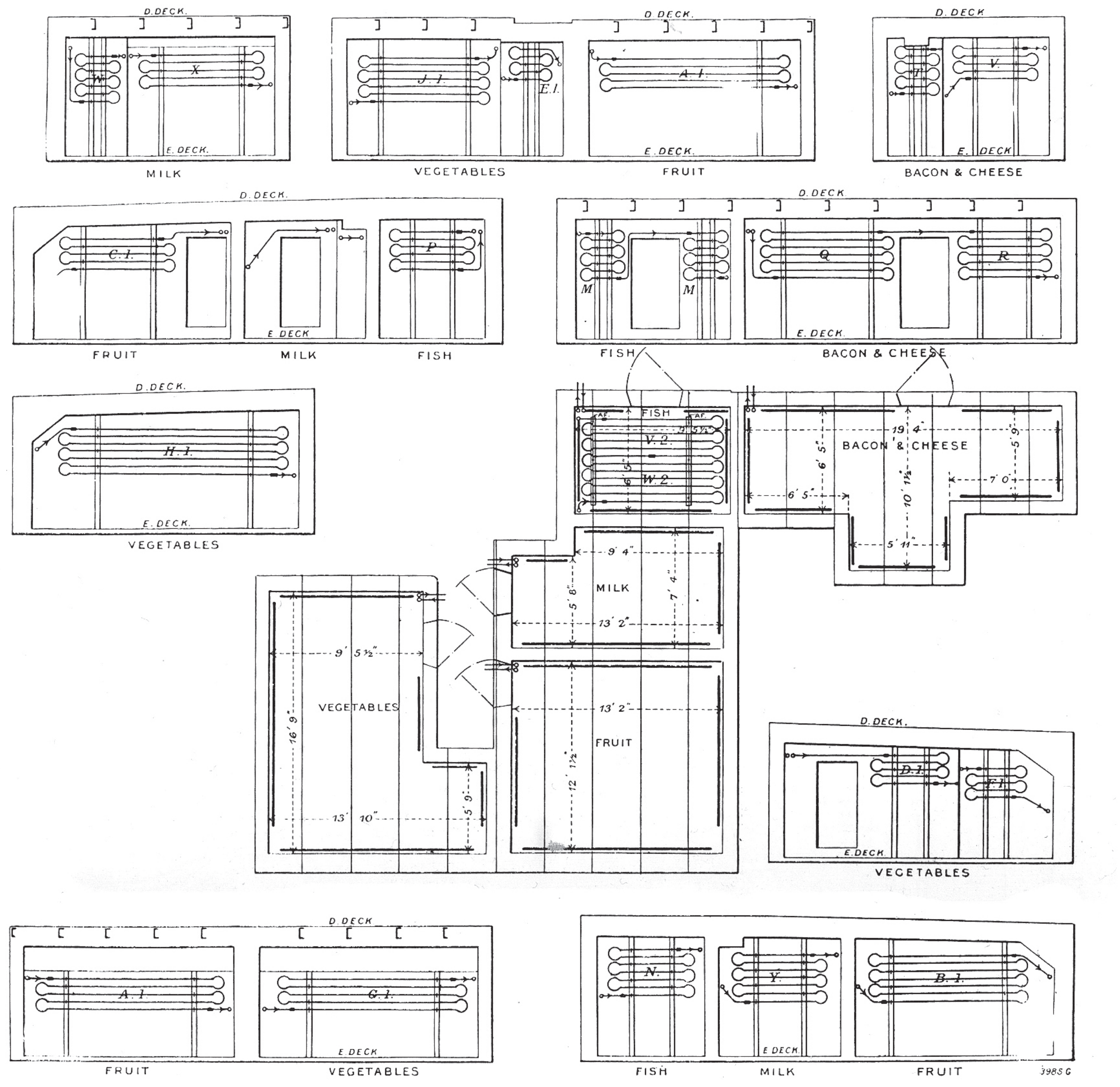


Fig. 18-10 **Ice-Making Machine on *Ceramic*** – The ice-making machine on the White Star Liner *Ceramic c.*1913. The one shown here is very similar to those used on the *Olympic*-class liners. *(H&W/Authors' collection)*



ARRANGEMENT OF BRINE-PIPING IN FRUIT, VEGETABLE, &C., CHAMBERS.

Fig. 18-11 **Arrangement of Brine Piping** – Plan views of the *Aquitania*'s brine piping in way of the Fruit and Vegetable store rooms. There is no plan known to exist like this for *Titanic* or *Olympic*. In order for the reader to understand how an ocean liner's brine pipes were fitted, this illustration is a good reference. *Aquitania*'s refrigeration system, though manufactured by a different company, was similar to *Titanic*'s. (The Engineer/*Authors' collection*)

harm; this could not be said of charcoal insulation. Over time it was determined that the cork lining forming the containing walls needed only to consist of a single thickness of 1in boarding, half-checked at the edges. This was also much less costly.

Cork was obtainable in compressed slabs of almost any size, shape, and thickness. In order to ensure that no settling or vacant spaces had developed, periodic inspections were made of the insulation. Test holes were bored in the inner wood lining where vacant spaces were most likely to occur. Such examinations were conducted by the Board of Trade on behalf of both the shippers and underwriters of the cargo, certificates being issued at the beginning of each voyage on the efficiency of the refrigerating machinery and insulation.

Insulation was also used as a heat barrier between casings and accommodations, and to mute sound. A prime example of sound muting was the insulated Silent Room built to house the Marconi transmitting equipment, which was very loud and obtrusive. Furthermore, insulation was used in the ceilings of the rooms underneath the Galleys to prevent both heat and noise from above. First Class accommodations which abutted otherwise loud passageways were insulated

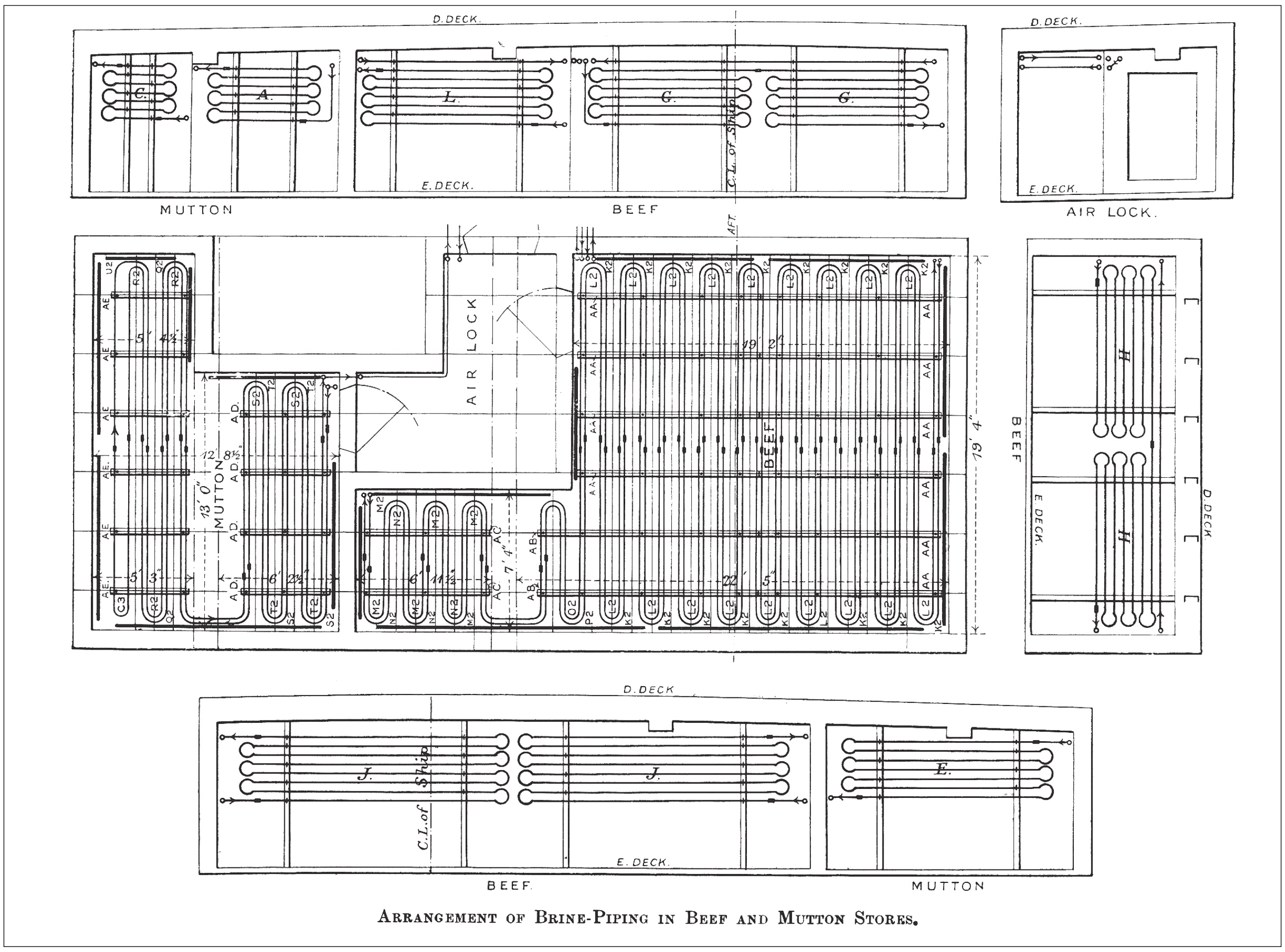

D. DECK
E. DECK
C.
A.
L.
G.
G.
C.L. of Ship
MUTTON
BEEF
AIR LOCK.
AFT
AIR LOCK
BEEF
MUTTON
19' 2"
19' 4"
13' 0"
12' 8½"
5' 4½"
5' 3"
6' 2½"
6' 11½"
7' 4"
12' 5"
H
H
J.
J.
E.
C.L. of Ship
BEEF
MUTTON
Arrangement of Brine-Piping in Beef and Mutton Stores.

Fig. 18-12 **Beef and Mutton stores on *Aquitania*** – Plan views of the brine piping in *Aquitania's* Beef and Mutton storage spaces. *(*The Engineer*/Authors' collection)*

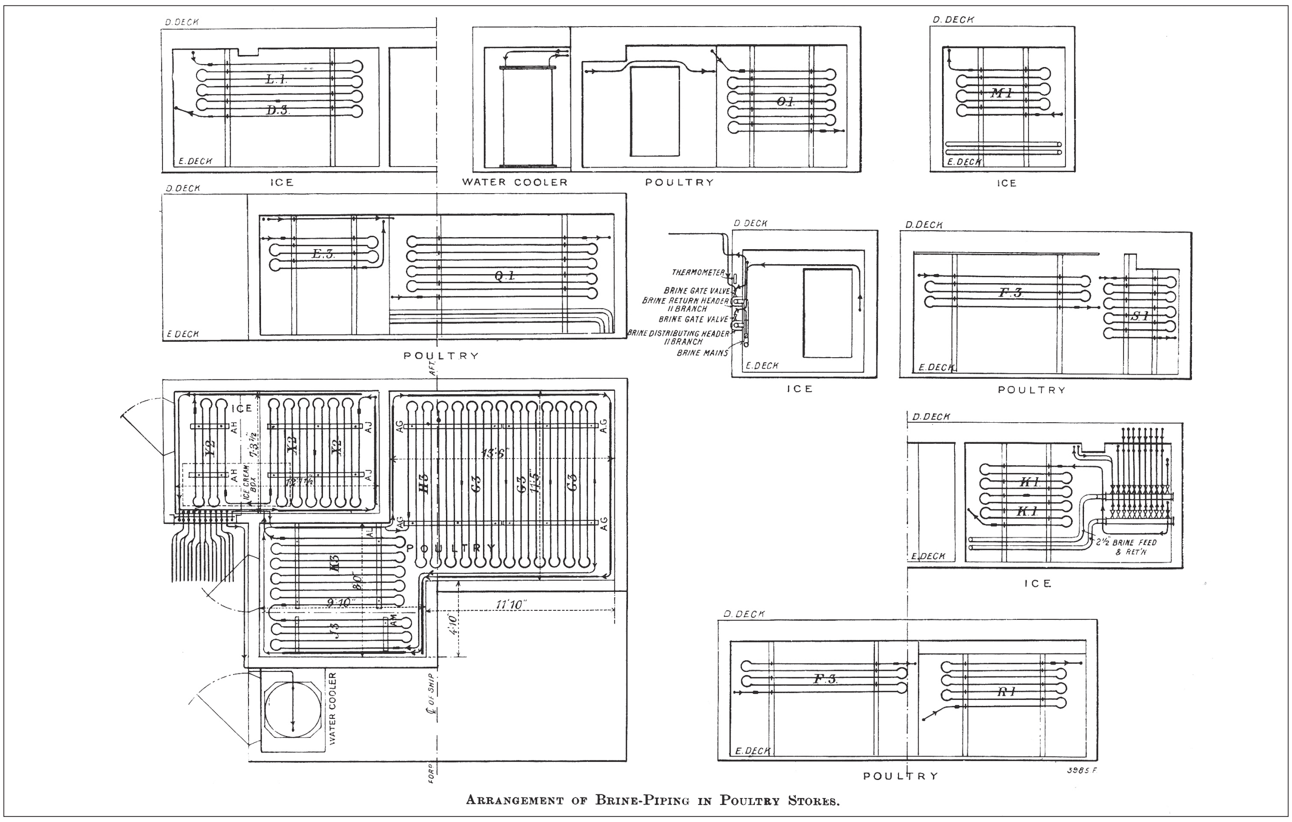

D. DECK
E. DECK
L.1.
D.3.
O.1.
M.1.
ICE
WATER COOLER
POULTRY
ICE
E.3.
Q.1.
POULTRY
THERMOMETER
BRINE GATE VALVE
BRINE RETURN HEADER
11 BRANCH
BRINE GATE VALVE
BRINE DISTRIBUTING HEADER
11 BRANCH
BRINE MAINS
ICE
F.3.
S.1.
POULTRY
ICE
K.1.
K.1.
2½" BRINE FEED & RET'N
ICE
WATER COOLER
POULTRY
F.3.
R.1.
POULTRY
3985 F
Arrangement of Brine-Piping in Poultry Stores.

Fig. 18-13 **Poultry Stores on *Aquitania*** – Plan views of the brine piping in *Aquitania*'s Poultry storage spaces. *(*The Engineer*/Authors' collection)*

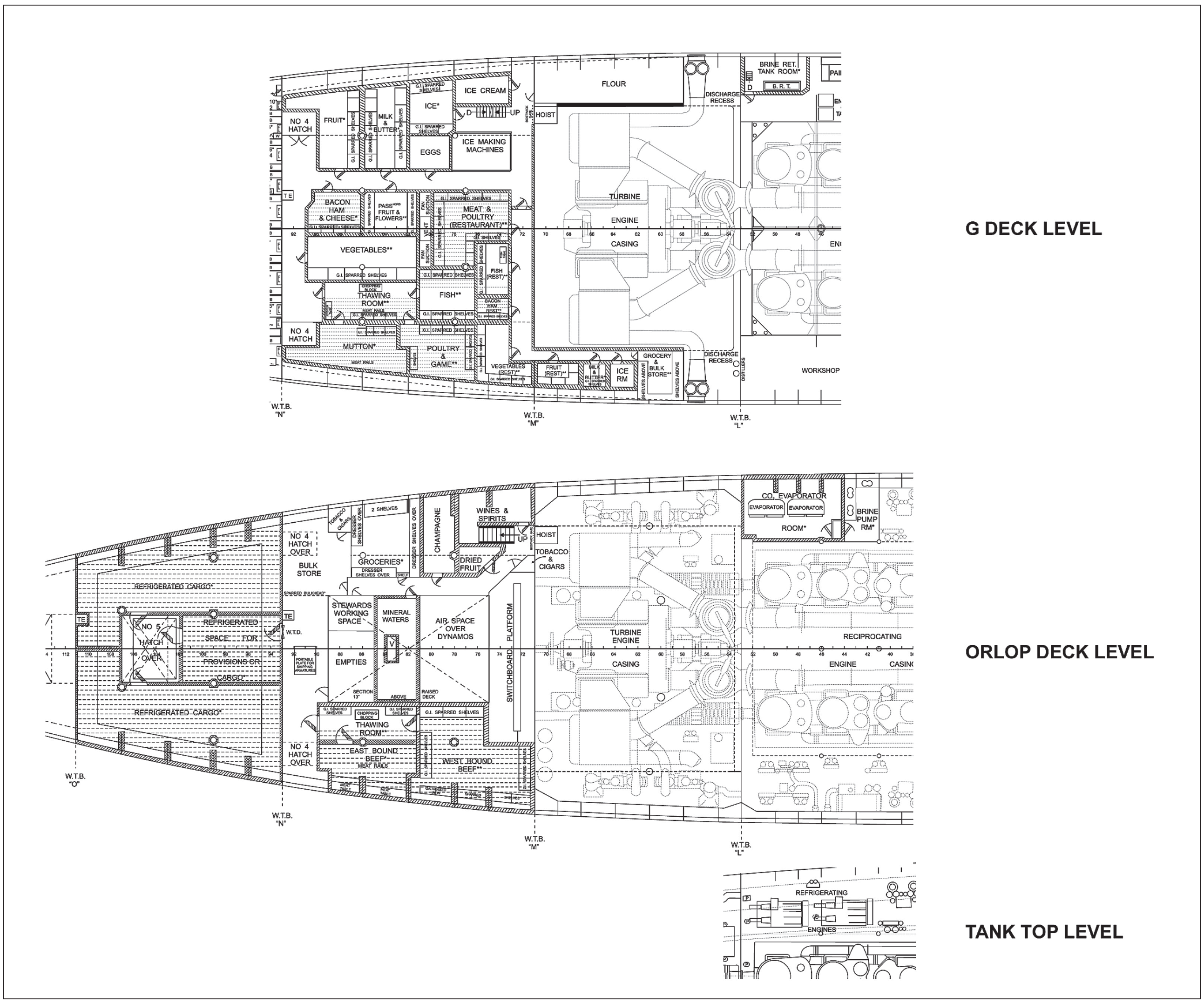

G DECK LEVEL
ORLOP DECK LEVEL
TANK TOP LEVEL
NO 4 HATCH
FRUIT*
MILK & BUTTER*
ICE*
ICE CREAM
EGGS
ICE MAKING MACHINES
FLOUR
HOIST
BRINE RET. TANK ROOM*
DISCHARGE RECESS
BACON HAM & CHEESE*
PASS FRUIT & FLOWERS**
MEAT & POULTRY (RESTAURANT)**
VEGETABLES**
THAWING ROOM
FISH**
FISH (REST)*
MUTTON*
POULTRY & GAME**
VEGETABLES (REST)*
FRUIT (REST)*
ICE RM
GROCERY & BULK STORE**
TURBINE ENGINE CASING
WORKSHOP
W.T.B. "N"
W.T.B. "M"
W.T.B. "L"
W.T.B. "O"
REFRIGERATED CARGO*
NO 5 HATCH OVER
REFRIGERATED SPACE FOR PROVISIONS OR CARGO*
BULK STORE
NO 4 HATCH OVER
GROCERIES*
CHAMPAGNE
WINES & SPIRITS
DRIED FRUIT
TOBACCO & CIGARS
STEWARDS WORKING SPACE
MINERAL WATERS
AIR SPACE OVER DYNAMOS
SWITCHBOARD PLATFORM
EMPTIES
EAST BOUND BEEF*
WEST BOUND BEEF**
CO2 EVAPORATOR ROOM*
EVAPORATOR
BRINE PUMP RM*
RECIPROCATING ENGINE CASING
REFRIGERATING ENGINES

Fig. 18-14 **Plan Showing Three Main Levels of the Refrigeration Plant** – The main levels of *Titanic*'s refrigeration plant and the primary spaces which it serviced. (Bottom) the Tank Top level with the main machinery, (middle) the Orlop Deck Level with the evaporators, brine circulating pumps, cold storage rooms for the ship's provisions and cargo, and (top) the G Deck level with additional cold storage and brine return tanks. The angled hash marks between the double bulkheads indicates insulation. *(Illustration by Bruce Beveridge)*

because of the noise; an example of this can be found in the First Class accommodations at the forward end of E Deck where two staterooms backed up against the working crew passageway with several more abutting an athwartship passageway containing two of the Third Class stairways. The same was true for passenger and crew accommodations which came into contact with the slop chutes, these being insulated with 2in cork slabs.

Cork slabs used as a heat barrier were positioned along boiler casings when abutting passenger accommodations. Thicker slabs, generally 2in cork, were used on the decks from C Deck on down, with 1½in slabs used on A and B Decks. Areas that radiated heat other than boiler casings, such as the bakery and around the roasters and ovens, were also insulated as necessary to prevent heat transmission to adjacent spaces. This insulation may not have been as effective as intended; First Class Saloon Steward Frederick Ray recalled that some of the staterooms on E Deck near the engine and boiler casings were found to be too hot even though the machinery casings in this area were lined with cork as described. (In Ray's opinion, this was where the vast amounts of cork came from that were seen floating on the water the morning after the sinking.)

Note

1. Large quantities of granulated cork were observed on the surface of the sea following *Titanic*'s foundering, particularly by those who were left struggling in the water. This was very likely the granulated cork insulation expelled following the implosion of the refrigerated compartments during the stern section's descent to the ocean floor.

Chapter 19

Ventilation and Heating

Ventilation may be generally described as the introduction of fresh air along with the simultaneous removal of air carrying odors, smoke, bacteria, excessive heat or excessive moisture. If the area ventilated is too cool, the incoming air may be heated.[1] Although the concept of 'climate control' was not described by that term in 1912, the basic principle was the same – providing for the comfort and well-being of those persons inside through ventilation and heating. Ventilation may be divided into two types, natural ventilation and forced ventilation, the latter accomplished by mechanical means. While *Titanic* did utilize some passive ventilation, the majority of her systems were the mechanical or motor-powered fan type. In addition, an integrated ventilation system was created rather than having a large number of dedicated ventilators serving only a specific room.

In the era when large sailing vessels predominated, ventilation of the lower decks was assisted by rigging canvas wind scoops in front of hatches and companionways to channel the breeze over the deck into the ship's interior. Later, aboard iron-hulled vessels, steel cowl vents took the place of canvas wind scoops; cowl vents are the large structures with enlarged or bell-shaped openings most commonly seen on the uppermost decks of ocean liners in many photographs. On some vessels they feature very prominently; on the *Mauretania*, for example, there is a veritable forest of cowls along the upper deck. *Titanic*'s ventilation system was designed to limit the number of cowls protruding from the weather decks, and this resulted in the superstructure of the ship having a very clean, uncluttered appearance.

In her construction, *Titanic* benefited from experience gained with *Olympic*. The ventilation systems initially provided on *Olympic* were not as effective as her builders had intended. There were complaints of staterooms being either too cold or too hot. The quantity of air extracted from the First Class Dining Saloon was found to be insufficient and electric fans had to be added along the ceiling to assist in moving air toward the exhaust gratings, as well as in the bays to combat the heat from the electric lights which made the room uncomfortably warm. Problems also occurred with the use of the No.4 Funnel, initially intended as an exhaust for hot air from the Turbine Engine Room. The ducts leading into the base of the funnel from other compartments brought in air that was cooler than the air that was coming up from the engine space; this dampened the natural convection that had been planned for and created an air lock, with the result that excessive heat built up within the height of the casing between the top of the turbine and the bottom of the funnel. Similarly, the ventilation was found inadequate in the Reciprocating Engine Room casing, where the heat throughout the top platforms was stifling.

The most serious deficiencies were corrected to some degree on the *Olympic* during her first year of service; these corrections and many additional improvements were integrated directly into the *Titanic*'s construction. Further improvements were implemented during the *Olympic*'s 1912–13 refit.

Natural ventilation

Natural ventilation is based on the principle that heat rises. Air circulating among hot machinery or in galley areas, for example, will become heated, expand – therefore decreasing in density – and rise on its own, to be replaced by cooler, denser air flowing in from an outside source. Even a roomful of people will cause convection currents within the air of the room, both from their body heat and respiration. The natural tendency of cold air to displace warm air was used in the Reciprocating Engine Room, for example, as the air heated by machinery moved upward to escape through the skylight. In the boiler rooms, the same movement of heated air occurred towards the fidley trunks. In both cases, fresh (cooler) air entered through supply ventilators. Consequently, in any space in the ship relying on natural ventilation, provisions were always made for at least two openings: one inlet at the lowest possible level for the admittance of cold air and an outlet as high as possible to remove warmed air.

Natural ventilation could be augmented by the wind or the forward motion of the ship. At sea, on a power-driven vessel that could achieve twenty knots or more, this could be a significant factor. The air streaming past was used to good advantage, not only by directing its flow downward into trunks or ducts into the internal parts of the vessel or into compartments contiguous with the vents, but also to induce an upward flow of air out of the ship. Effective ventilation required the use of both downcast and uptake ventilators, as any compartment being ventilated must be provided with a means to exhaust stale or foul air if an inflow of fresh air is to take its place. Cowl vents, as noted above, could be employed to direct the prevailing air stream over the deck into the ship's interior spaces, but they could also function as uptake ventilators. By positioning a cowl vent with its opening facing away from the direction of the air stream, an area of low pressure resulted at the mouth of the cowl, effectively drawing or pulling air up and out of the ventilator from within the ship. A limited number of cowl vents on *Titanic* functioned in this manner, with no mechanical assistance.[2] Other uptake ventilator heads based on this principle and employed on *Titanic* were the mushroom, Fyfe, Gibbs extractor, and gooseneck to name a few. The No.4 Funnel, which served primarily to ventilate the Galley spaces, also functioned in the same manner, aided by the funnel's height. As with the other funnels, its height alone caused a significant draft even in the absence of any airflow across the top, provided that the entry of cooler air into the base of the funnel was prevented.

Mechanical ventilation

Mechanical ventilation is the application of power to a system of air exchange. Mechanical ventilation – using powerful fans with electric motors to move air through ventilation ducts – had the advantage of ensuring an adequate air supply to all areas of the ship under all weather conditions because the inlets could be placed in areas protected from waves or spray; it also permitted ventilation independent of the vessel's forward motion or the lack of any wind over the decks. In addition, ventilation could be accomplished to interior spaces at a considerable distance from the source of supply, and through relatively small ducts over a route involving many changes of direction. Another benefit from fan ventilation was that a considerable velocity was imparted to the air. This had a cooling effect that could be felt at some distance from the ventilation aperture in the compartment. It was, therefore, not always necessary to extend the supply trunk to the bottom of the space (near the deck) as was required for natural ventilation. Air in motion, however, could be disadvantageous if it was felt as a draft in a public room. Therefore, care was to be taken in arranging louvers to ensure that the cool air stream did not impinge on the passengers.

Mechanical ventilation used on *Titanic* was on the 'plenum' or 'pressure' system, meaning that supply fans forced incoming air through a system of ducts leading to the areas of the ship being ventilated. Exhaust fans drew air out via a separate system of ducts. Air in passenger and crew accommodations was normally changed at least ten times per hour, although in cold weather this would be considerably reduced. The plenum system, utilized with an accompanying exhaust system, was generally considered to be the most economical with regard to the power required. In colder months, the feed air on the plenum system was also heated, using two methods of ventilation called 'warm air' and 'hot air'. There were instances where fresh air was passed without being modified, but this was generally done in compartments already heated by machinery or appliances.

Ventilation of Interior Spaces

Ventilation of passenger accommodations

In the early days of ocean travel, passenger accommodations consisted of small, dark and stuffy spaces which were not only uncomfortable, but also very injurious to health due to the often-fetid atmosphere. However, by the turn of the twentieth century, tremendous advances had been made to the accommodations and in the way in which they were supplied with air and light. *Titanic*'s passenger staterooms and cabins in particular were provided with highly effective ventilation.

The typical ventilation arrangement on *Titanic* consisted of overhead supply trunks with branches into various blocks of rooms. Supply fans sent air via these trunks into the passageways and staterooms, and exhaust fans pulled air from the lavatories. The two systems thus formed one circuit; the fresh air ventilated the passageways and passenger quarters and was then passed, by way of the louvers in the doors and bulkheads, through to the lavatories and then drawn out to the open air by way of exhaust trunks. This also had the advantage of preventing any odors from affecting the adjacent rooms or corridors. It was preferable to introduce the fresh air at a lower level and exhaust from a higher level – usually between the beams at the deck head – to take advantage of the natural tendency for heated air to rise. Separate fans for opposite sides of the ship were generally employed as ventilation requirements on the weather side of the ship were not the same as on the lee side and the two sides needed to be regulated independently. It should also be noted that for those cabins adjoining the hull, sidelights were intended to provide ventilation as well as light.

Some stateroom doors were fitted with a type of ventilator called a louvered panel, which permitted air supplied to a passageway to pass into the stateroom. In these instances, one or more of the solid panels of a door were replaced by a series of louvers. These louvers, which could be arranged either horizontally or vertically, allowed air to pass between them, but were overlapped so as to prevent direct vision into the room.[3]

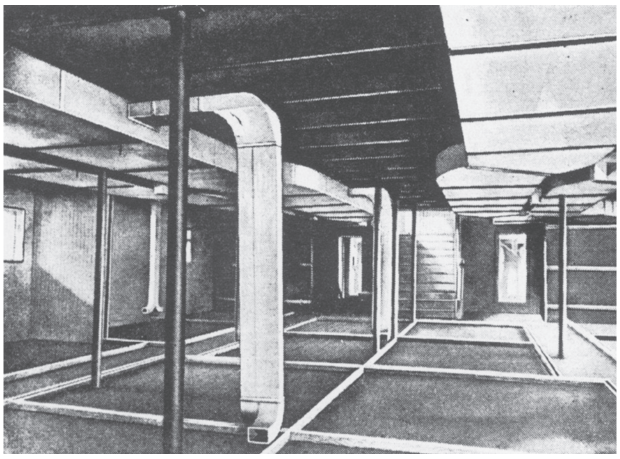


Fig. 19-1 **Installation of Heating Ducts** – This shows a typical installation of galvanized-steel air ducts in a cabin space. The ducts will be concealed later by paneling and interior fittings. The outlines of what will become the cabins and corridors are easily discerned by the presence of the 'cants' – the wooden coamings for the partitions – which have already been laid on the deck.

In addition, the 'Bibby principle' was employed throughout the ship to provide natural ventilation by means of sidelights to interior staterooms that were not in direct communication with the sides of the ship. The Bibby principle, named after the Bibby Line which first employed it, meant that staterooms immediately inboard of the those adjacent to the ship's sides were designed with a narrow corridor connecting with the hull, the narrow corridor giving access to a sidelight that provided light and ventilation to the inboard stateroom. The staterooms adjoining the hull were relatively shorter in length to accommodate this design. The Bibby principle was employed on B, C, D, E and F Decks, and in addition, interior corridors were provided with side corridors running athwartships to the hull at frequent intervals to provide natural ventilation to the passageways. These side corridors were employed throughout the ship from A Deck down to G Deck.

In the Third Class accommodations, including those where the bulkheads were portable (so that the rooms could be dismantled and cargo carried in place of passengers), the ventilation trunks were usually located in the corridors and had no branches; incoming air found

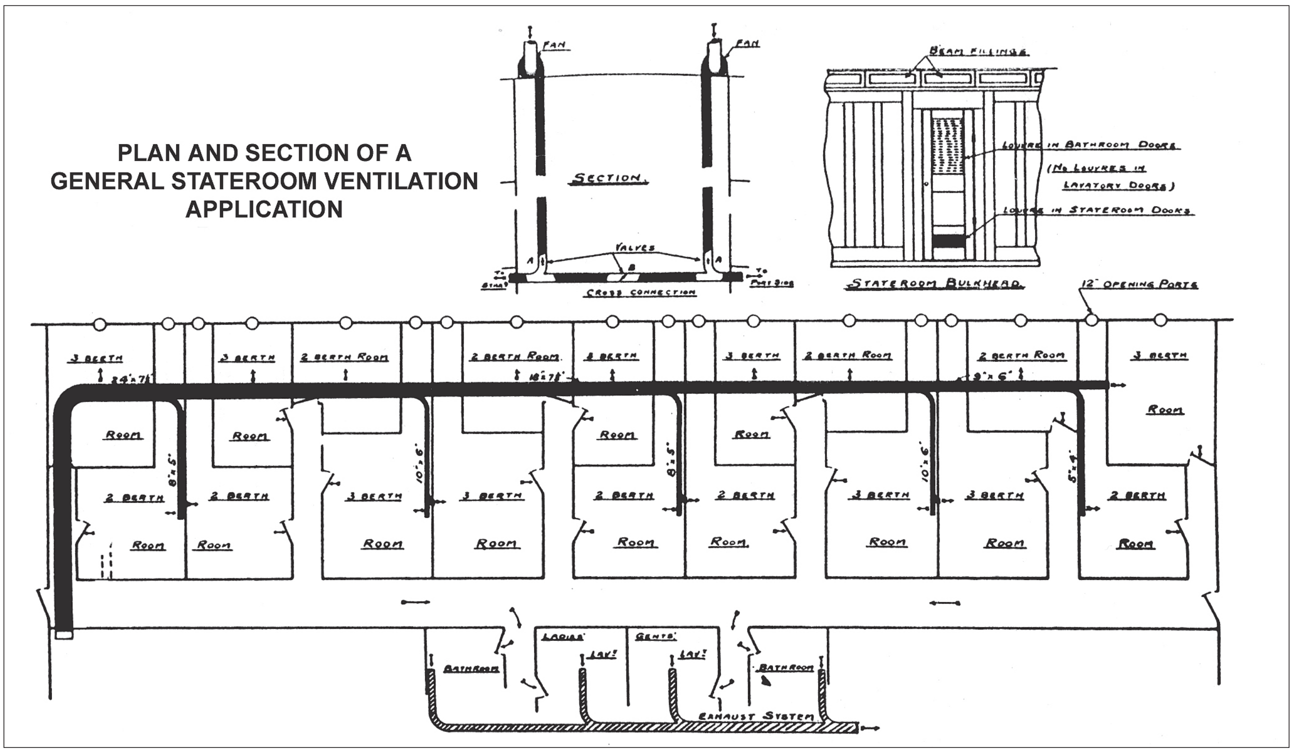

PLAN AND SECTION OF A GENERAL STATEROOM VENTILATION APPLICATION
FAN
FAN
SECTION.
VALVES
A
B
A
TO STAR'D
TO PORT SIDE
CROSS CONNECTION
BEAM FILLINGS
LOUVRE IN BATHROOM DOORS
(NO LOUVRES IN LAVATORY DOORS)
LOUVRE IN STATEROOM DOORS
STATEROOM BULKHEAD.
12" OPENING PORTS
3 BERTH
2 BERTH ROOM
3 BERTH
Room
2 BERTH
3 BERTH
Room
LADIES' LAV.
GENTS' LAV.
BATHROOM
BATHROOM
EXHAUST SYSTEM

Fig. 19-2 **General Plan of Stateroom Ventilation** – This installation plan shows the routing of air ducts for a series of cabins in a typical shipboard installation.

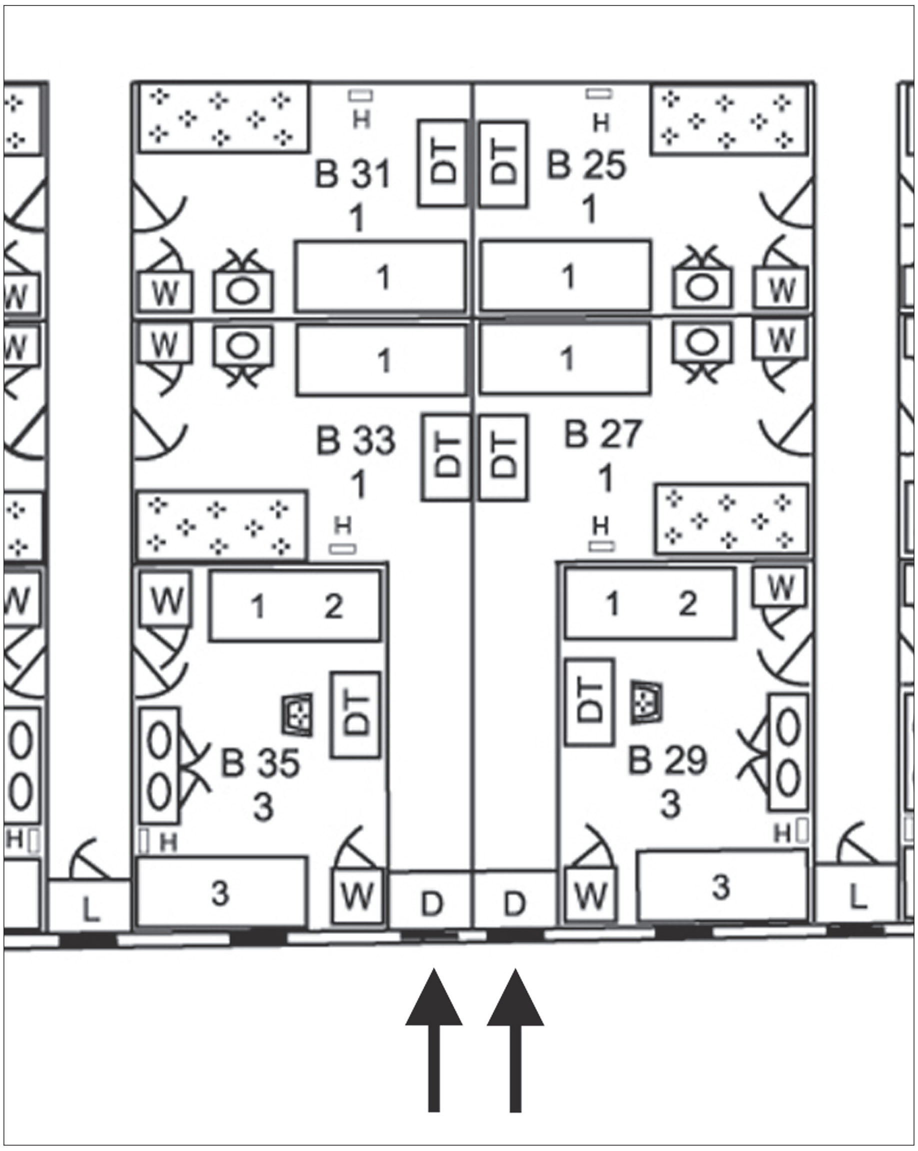


Fig. 19-3 **Bibby Principle of Ventilation** – In this detail from the General Arrangement plans of B Deck, it can be seen that staterooms B 33 and B 27, located inboard of staterooms B 35 and B 29, were each provided with a small corridor leading to the ship's side, where a sidelight was fitted. To either side of this block of rooms, the athwartship corridors giving access to these staterooms from the main fore-and-aft corridors were also extended to the ship's side; here, a linen locker was provided, with a sidelight located above. *(Illustration by Bruce Beveridge)*

its way into the rooms through the spaces between the beams. The top and bottom panels of the doors were louvered and additional openings were often made in the bulkheads to facilitate air circulation. The one disadvantage encountered in this arrangement was some loss of privacy, albeit minimal, as rooms having such a large number of ventilation openings offered very little in the way of soundproofing.

Ventilation of Galleys and public rooms

The Dining Saloons were provided with supply systems designed around the number of occupants allowable within each space. Inflow of air was generally provided through the brass grates seen at deck level and through supplemental ducting. The exhaust of air was accomplished through ducts leading to fans on the Boat Deck and through the natural flow of air through the doorways into the adjoining Pantries.

Special attention was given to the Galleys where the culinary operations were carried out. On *Titanic*, besides the main Galley areas where the large ranges were situated, there were separate rooms for preparing fish, vegetables, confections, bread, etc., as well the Sculleries. A Butcher's Shop and numerous store rooms were also provided, and each of these compartments required adequate ventilation.

The Galley areas needed special attention due to the heat generated by the equipment and because cooking aromas, particularly in rough weather, could be very unwelcome in the passenger quarters. Considerable quantities of steam were given off by vegetable boilers, plate-washing machines, etc., and a good supply of fresh air was necessary to carry away the moisture which would otherwise be deposited on the deck head and beams. The health and comfort of the men working in the Galleys was also a matter of concern as many of these spaces such as the Bake Shop were comparatively small and liable to become very hot. It was found that a system of exhaust fans drawing out the heated air, steam and fumes would pull in sufficient fresh air through skylights, ports in the ship's side and communicating doors and alleyways. The exhaust of *Titanic*'s galleys was accomplished through the No.4 Funnel as mentioned earlier, the fans being located within a corresponding deckhouse on the Boat Deck. The flues from the ranges and ovens were run beneath the deck instead of above, which eliminated a key source of excessive heat within the galleys.

A common and convenient arrangement in designing large ocean liners was to place the galleys between dining saloons for two separate classes of passengers. The exhaust fans drawing air out of the galley spaces then ventilated these saloons to a large extent by drawing air through the connecting doors and special openings into the galley spaces. This was the case with the First and Second Class Galley on *Titanic*, which was located between the First Class Dining Saloon and the Second Class Dining Saloon.

The ventilation of the First Class Smoke Room, the First Class Reading and Writing Room and the First Class Lounge were based on intended occupancy, allowing for a certain amount of natural air entering by way of doors and windows. Many of *Titanic*'s First Class public rooms were located on A Deck, with raised roofs extending up through the Boat Deck level. These rooms were provided with large, opening windows as well as exhaust fans fitted on top of the deck that formed the raised roofs; the fans drew air through grids fitted in the ceiling paneling or in decorative beam and stringer casings. Fresh air was supplied by fans through rectangular trunks generally 20in x 5in in cross-section within the rooms, the air entering the rooms through louvers or brass grilles seen at deck level and through other supplemental ducts hidden within the décor of the compartments.[4]

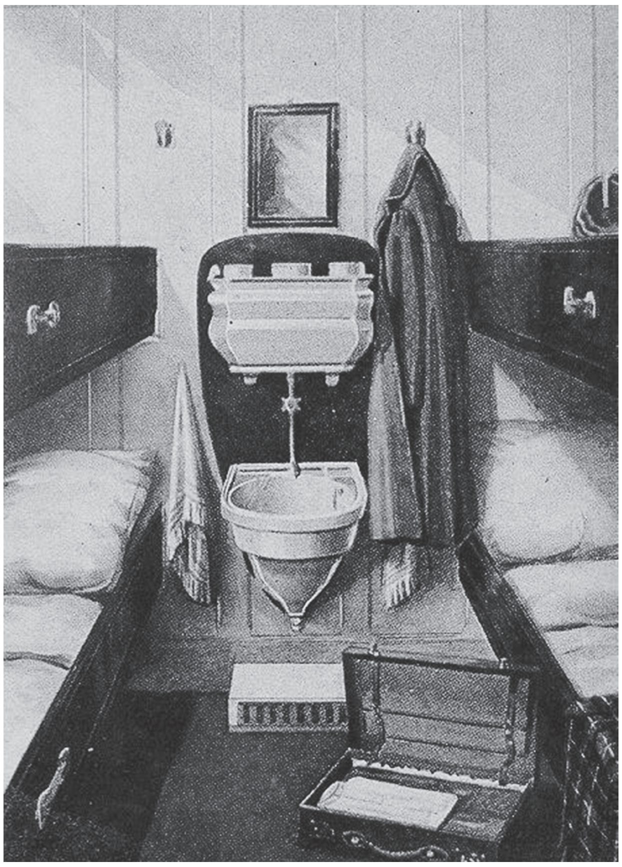


Fig. 19-4 **Third Class Cabin** – An artist's rendition of one of *Olympic* and *Titanic*'s Third Class cabins in the after end of the ship. The floor-level ventilation duct can be seen below the washbasin.

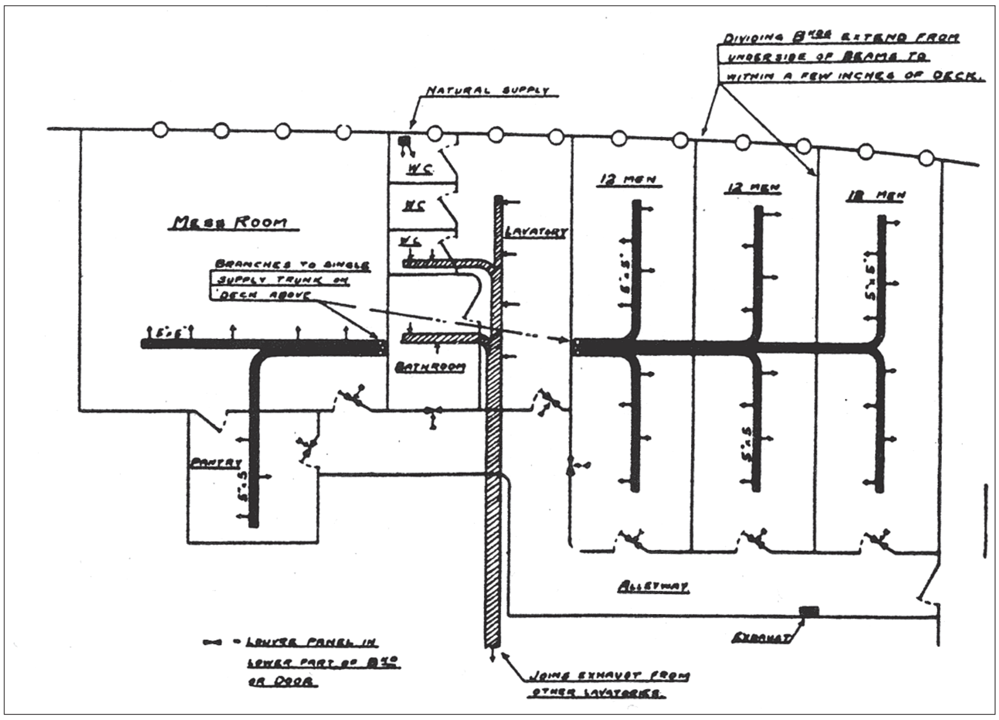

DIVIDING B'HDS EXTEND FROM UNDERSIDE OF BEAMS TO WITHIN A FEW INCHES OF DECK.
NATURAL SUPPLY
W.C.
W.C.
W.C.
LAVATORY
MESS ROOM
12 MEN
12 MEN
12 MEN
BRANCHES TO SINGLE SUPPLY TRUNK ON DECK ABOVE
6"x5"
6"x5"
5"x5"
BATHROOM
PANTRY
5"x5"
5"x5"
ALLEYWAY
EXHAUST
= LOUVRE PANEL IN LOWER PART OF B'HD OR DOOR
JOINS EXHAUST FROM OTHER LAVATORIES

Fig. 19-5 **General View of Ventilation of Crew's Quarters** – Example of a typical crew area ventilation layout. Though this does not depict the crew's quarters for an *Olympic*-class liner, the layout is very similar to the port side of E Deck in the area of the Engineers' Mess.

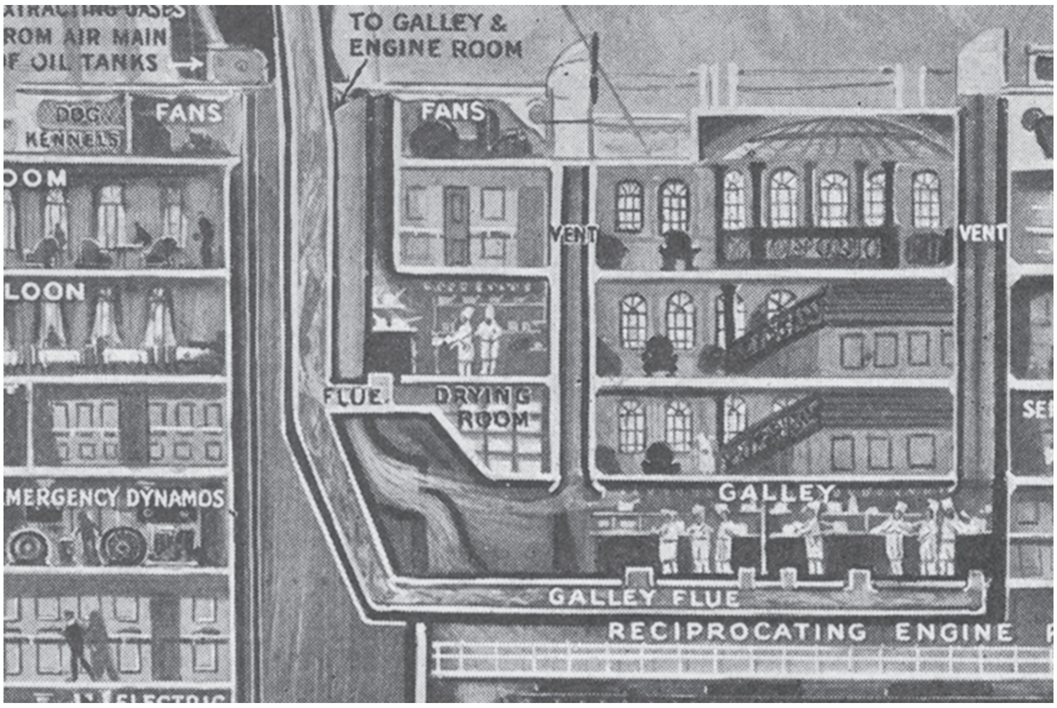


Fig. 19-6 **Illustration of Galley Flue** – In this detail from a period cut-away illustration, the flue for the ranges and ovens on *Olympic* can been seen, showing the exhaust of hot air and gases up and out the No.4 Funnel. Note that the flue runs beneath the deck, not overhead. This was an innovation intended to reduce heat in the galleys. *(William Daystrom collection)*

Ventilation of crew's quarters

Proper ventilation of these quarters was provided not only for humanitarian reasons and to comply with Board of Trade regulations, but for financial reasons as well. The running of the vessel and the safety of the ship, her passengers and cargo depended on the efficiency and vigilance of the crew who would be unable to perform their duties properly unless they were healthy and well-rested.

It was generally agreed that mess rooms be kept separate from sleeping quarters so that a minimum amount of air could be supplied to the former and a maximum to the latter, thus ensuring comfort in cold weather for men sitting in the mess room while giving ample amounts of fresh air to those sleeping in the confined areas available on board ship. Mechanical ventilation was used for crew spaces aboard *Titanic* and included a supply into the passageways and then over or under partitions and through louvers into rooms. Many of the crewmen's berthing compartments were also provided with doors fitted with louvers and frets to enhance air circulation. The Victualling crew and Seamen's quarters, including the Engineers' Mess along the working crew passageway on E Deck, were fitted with either fall-in flaps or pivoting wood shutters on the bulkheads to allow air to circulate from the passageway as needed. Every effort was made to avoid drafts because not only were they uncomfortable, but crewman would quickly put an end to any draft by blocking up the offending ventilator.

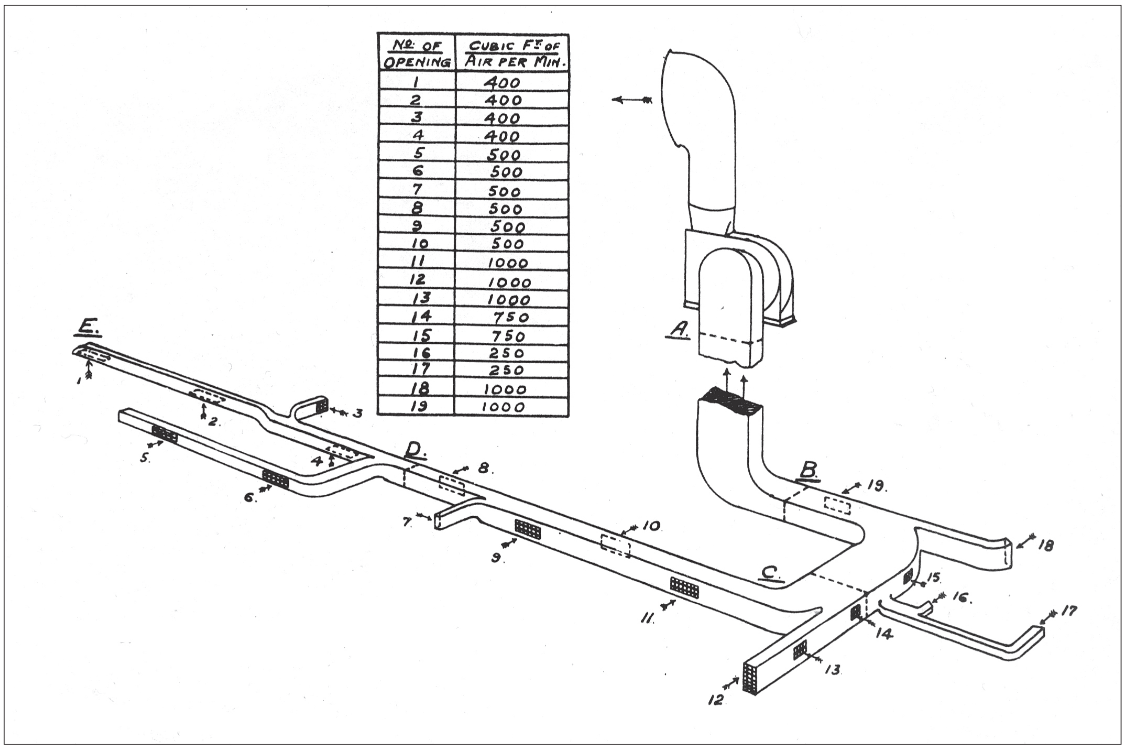
In large passenger liners such as *Titanic*, much of the crew was housed below decks in an area where a mechanically-assisted air supply was essential. The crew berthing accommodations at the bow were fitted with opening sidelights, with the lavatories placed at the side of the ship where they were also well ventilated.

Air Trunks and Fans

Air trunks

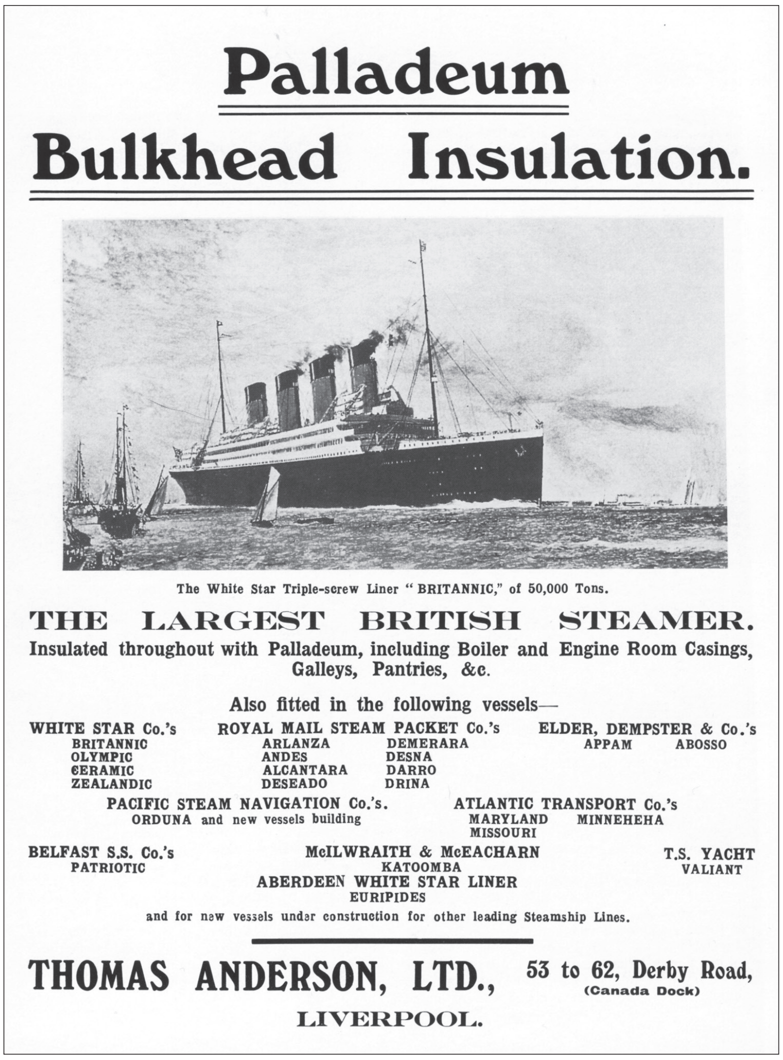
The systems of air ducts or trunks could be short and simple, if ventilating a limited number of spaces higher up in the ship, or could be of considerable length and complexity if leading to a larger number of compartments on one of the lower decks. Owing to the great length that some of the trunks had to run, sharp bends and sudden changes of form were to be avoided to prevent decreasing the flow of air. The connections of the suction (exhaust) trunks, which were vital for removing 'vitiated air'[5] were specified to not have an angle of more then 30° where they entered the main ducting.

Trunks of rectangular section were generally adopted in ship ventilation installations. Air trunks were constructed in a variety of ways and, although sometimes of wood, were usually galvanized sheet steel of 16 or 18 SWG (Standard Wire Gauge). The straight runs were usually fabricated in 6ft sections, each length consisting of one plate bent to the form required and hook-jointed at one corner. The various lengths were generally bolted together for convenience of fitting and handling.



No. of Opening	Cubic Ft. of Air per Min.
1	400
2	400
3	400
4	400
5	500
6	500
7	500
8	500
9	500
10	500
11	1000
12	1000
13	1000
14	750
15	750
16	250
17	250
18	1000
19	1000

Fig. 19-7 **Typical System of Air Trunks.**



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Bulkhead Insulation.

The White Star Triple-screw Liner "BRITANNIC," of 50,000 Tons.

THE LARGEST BRITISH STEAMER.

Insulated throughout with Palladeum, including Boiler and Engine Room Casings, Galleys, Pantries, &c.

Also fitted in the following vessels—

WHITE STAR Co.'s
BRITANNIC
OLYMPIC
CERAMIC
ZEALANDIC

ROYAL MAIL STEAM PACKET Co.'s
ARLANZA
ANDES
ALCANTARA
DESEADO
DEMERARA
DESNA
DARRO
DRINA

ELDER, DEMPSTER & Co.'s
APPAM
ABOSSO

PACIFIC STEAM NAVIGATION Co.'s.
ORDUNA and new vessels building

ATLANTIC TRANSPORT Co.'s
MARYLAND
MISSOURI
MINNEHEHA

BELFAST S.S. Co.'s
PATRIOTIC

McILWRAITH & McEACHARN
KATOOMBA

T.S. YACHT
VALIANT

ABERDEEN WHITE STAR LINER
EURIPIDES

and for new vessels under construction for other leading Steamship Lines.

THOMAS ANDERSON, LTD., 53 to 62, Derby Road,
(Canada Dock)
LIVERPOOL.

Fig. 19-8 **Palladeum Bulkhead Insulation Advertisement** – A Palladeum bulkhead insulation advertisement highlighting the *Britannic*, with *Olympic* mentioned. *(*The Shipbuilder*/Authors' collection)*

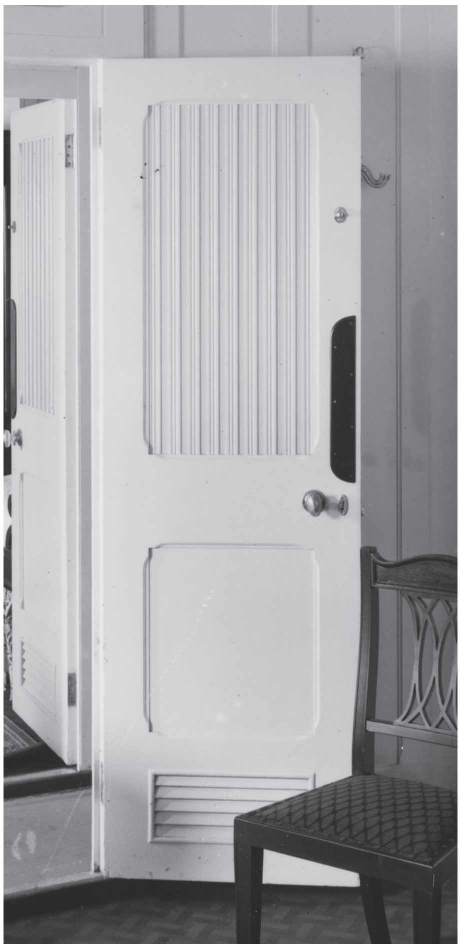


Fig. 19-9 **Door with Louvered Panel** – A typical stateroom door fitted with louvers in the bottom panel. *(Daniel Klistorner collection)*

However, they were often riveted at the joints whenever longer lengths could be readily placed in position and were not required to be removable for access or repairs. Care was taken to arrange the overlapped edges in the trunks so that they were facing in the same direction as the airflow, in order that air would not blow out of any part of the joint that was not tightly connected.

Air ducts susceptible to damage by cargo, such as those ducts in or near hatchways, were constructed of heavier plating and suitably stiffened. Large ducts of light plating also required stiffening; this was provided by hangers securing the trunk to the deck beams. Hangers were usually flat or angle-bar section. Ducts of considerable width sometimes had internal stiffening in the form of longitudinal tie plates between the flat sides. The hangers could be bolted or riveted to the beams. They could encircle the trunk to stiffen the underside or, in the case of small ducts, were attached only to the sides. All trunks were made as airtight as possible. This applied particularly to lavatory, hold or bunker ventilation trunks passing through passenger or crew quarters, and mica flaps were fitted in the suction trunks into staterooms along the boiler casings to prevent backdrafts.

Overhead ducts conveying warm air were insulated with 'Palladeum' magnesia[6] coverings manufactured by Thomas Anderson Ltd, while the trunks at deck level were covered in cork insulation. Vertical trunks, especially in machinery spaces, were usually provided with drip trays at the bottom to collect condensation.

Cleaning doors or hand holes were fitted at suitable positions and also served for access to the bolts of the joints when the trunks were being erected. Exhaust ducts from Galley ranges, grills, etc., frequently became coated internally with grease or fat and could become partially choked if not cleaned periodically. A more serious risk was the danger of fire, minimized by fitting dampers operated from the galley and designed to shut off the air supply to localize any fire which might occur. Trunks in which an accumulation of oil or oily vapor was likely to occur were not led through passenger accommodation or machinery spaces, due to the possibility of fire in the ducts spreading to adjoining compartments.

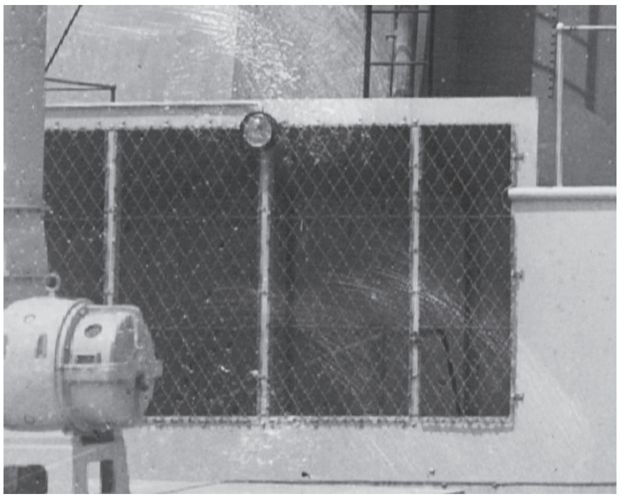


Fig. 19-10a **Wire Mesh Grate Over Duct** – An example of wire mesh grates covering the opening of one of *Olympic*'s stokehold intake ducts. Note the deck light mounted at the top of the housing.

The outlets from air trunks varied, but the most common was the 'hit-and-miss' ventilator. This consisted of a long, fixed rectangular plate with vertical slots through which the air passed. A similar plate of slightly smaller dimensions but with matching slots was placed

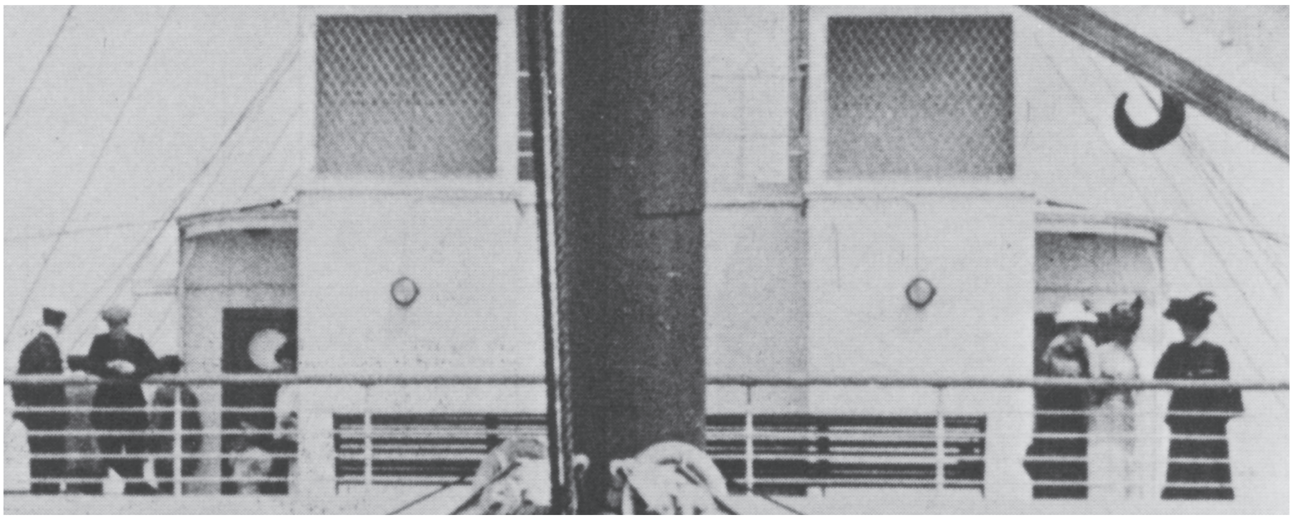
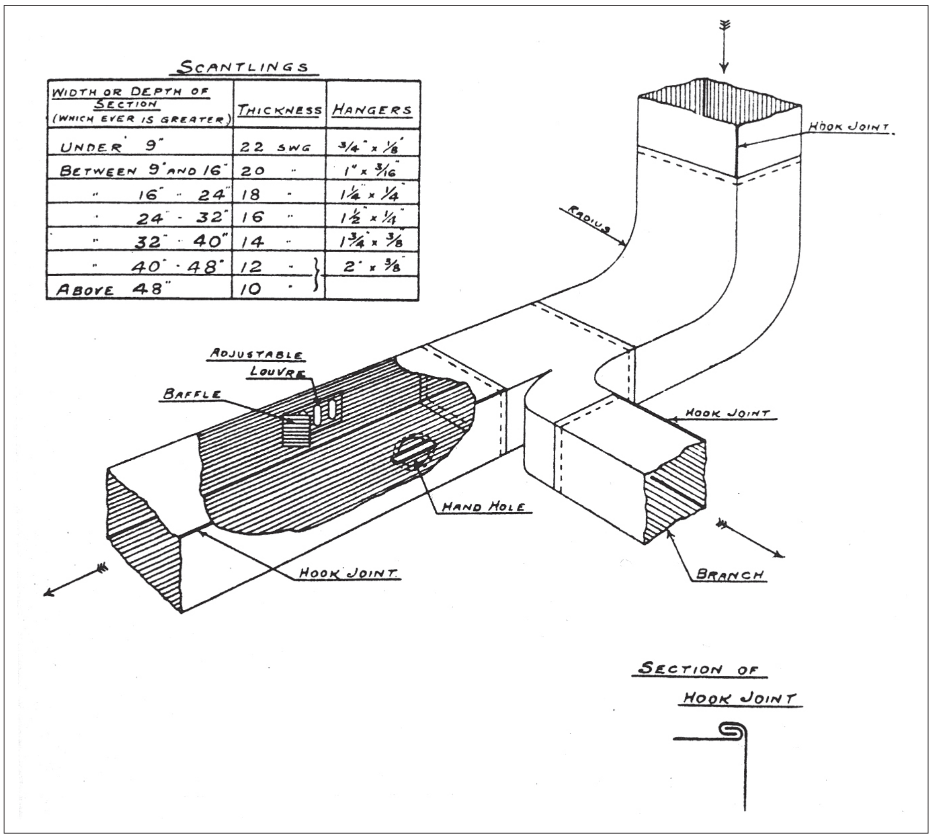


Fig. 19-10b **Second Class Entrance** – Wire-mesh grates cover the two huge ducts that flanked the after end of the Second Class Entrance on the *Olympic*'s Boat Deck. These ventilators also served as trunks to run the cables up from the feeder switchboard on the Orlop Deck before they branched out to other areas of the ship.



SCANTLINGS

WIDTH OR DEPTH OF SECTION (WHICH EVER IS GREATER)	THICKNESS	HANGERS
UNDER 9"	22 SWG	3/4" x 1/8"
BETWEEN 9" AND 16"	20 "	1" x 3/16"
" 16" " 24"	18 "	1¼" x ¼"
" 24" " 32"	16 "	1½" x ¼"
" 32" " 40"	14 "	1¾" x 3/8"
" 40" " 48"	12 "	2" x 3/8"
ABOVE 48"	10 "	

Fig. 19-11 **Detail of Typical Air Trunk**.

behind it. By means of a knob projecting through the front plate, the rear plate could be slid back and forth. If the slots were aligned, air would pass freely through; if the rear plate was slid partially to the side a lesser amount of air would pass, and if slid all the way to the side no air would pass. Ventilators were generally increased in area in proportion to their distance from the fan. Those at the extremity of long trunks were usually 50 per cent greater in area than the ventilators near the fan. The last ventilator was typically 3in from the extreme end of the trunk. Hit-and-miss ventilators were sometimes made of sheet steel, but more generally of brass. When of steel, they were always galvanized, oxidized or plated to prevent corrosion and to permit them to slide freely. Although commonly described as louvers, the term louver more correctly applied to the slatted wooden ventilation panels fitted in stateroom doors as described earlier.

Baffles were fitted at various points within supply ducts to help equalize the flow of air throughout the various systems. Moving air exerts a greater pressure at the outer circumference of a bend due to centrifugal force, and therefore the area of greatest airflow is along the outer side of the bend, with minimal airflow along the inside. Consequently, unless extended baffles or diaphragms were fitted, the airflow would be very poor to outlets located along an inside bend, or in branches coming off an inside bend. Baffles were, therefore, usually fitted at outlets and where branches left the main trunk. They were also necessary in the form of guide vanes at bends, especially where there were branches or outlets on the inner side. Similar guides were also required wherever the direction of the air stream changed and were sometimes necessary at enlarged outlets which discharged at an angle to the supply trunk or at right-angle bends where the inner radius was the same or less than the width of the trunk.

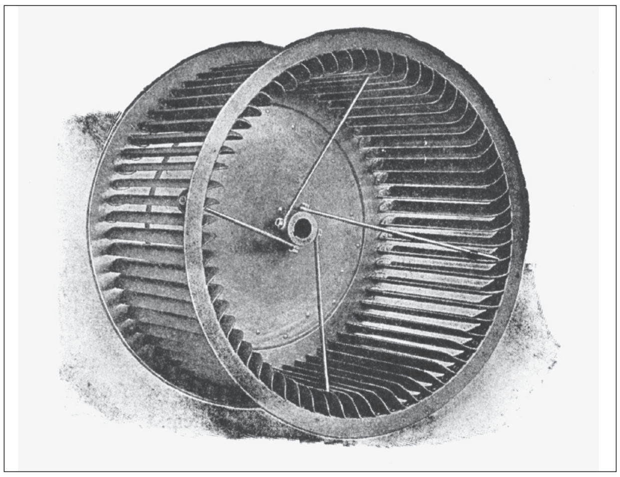
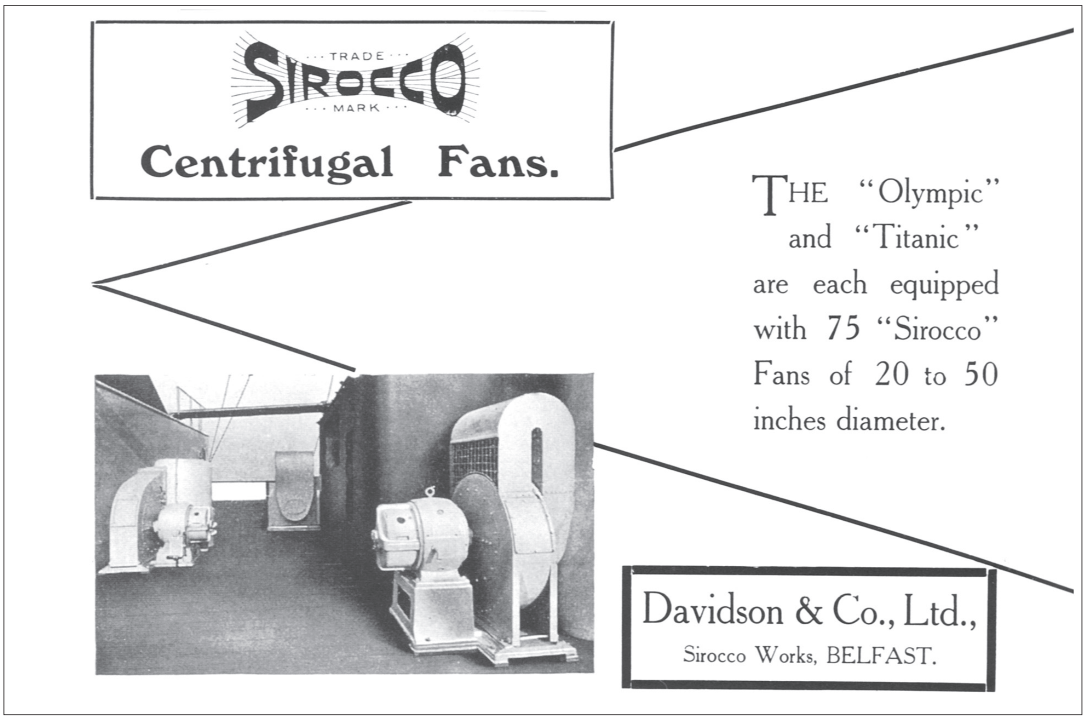


Fig. 19-12 **Sirocco Fan**.

For exhaust trunks, grids of some type had to be fitted over all inlets to prevent rubbish or other things being thrown in or drawn in. Expanded-metal grates were sometimes used, but as this offered a high resistance to



TRADE
SIROCCO
MARK

Centrifugal Fans.

THE "Olympic" and "Titanic" are each equipped with 75 "Sirocco" Fans of 20 to 50 inches diameter.

Davidson & Co., Ltd.,
Sirocco Works, BELFAST.

Fig. 19-13 **Davidson & Co. Advertisement**. (*The Shipbuilder/ Authors' collection)*

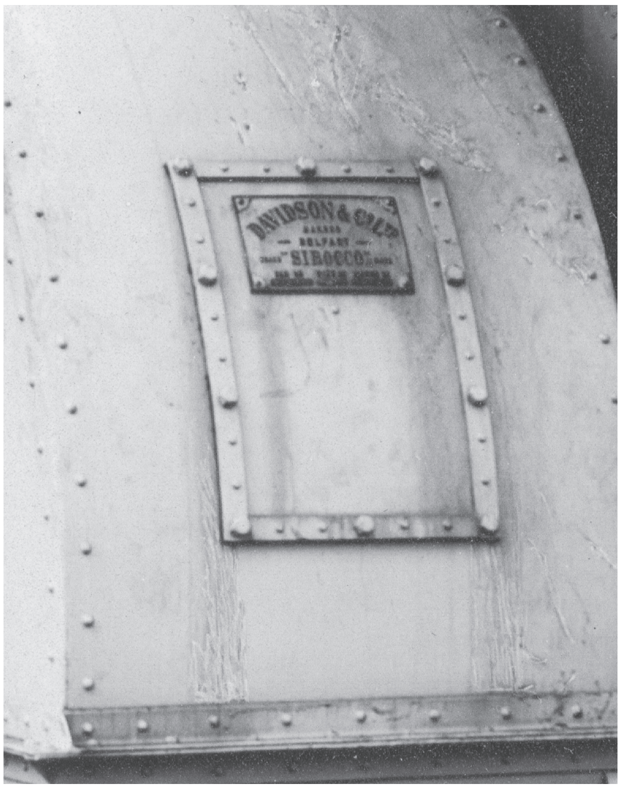


Fig. 19-14 **Davidson Name Plate** – An enlargement of the name plate on a Sirocco unit supplied by Davidson & Co. Ltd.

the passage of the air, an ordinary wire-mesh grating was preferable. Sometimes perforated plate grids with relatively large openings and small bars were adopted. All openings in pantries and storerooms and certain cargo spaces were fitted with grids as a protection against rats and pilferage.

The Sirocco ventilating fan

For assisting ventilation by mechanical means, *Titanic* utilized centrifugal fans driven by motors powered by the ship's electrical plant. The centrifugal fan operated on an entirely different principle from the axial fans that most people are familiar with in the form of table or window fans, also referred to as 'propeller fans'. Centrifugal fans, also called radial fans, operate on the principle that air has weight and is therefore affected by centrifugal force. Centrifugal force is that which tends to cause rotating bodies to move outwards or away from the point about which they revolve. A centrifugal fan moves air by means of an impeller, which consists of a central shaft about which are fixed rectangular blades. As the impeller rotates, air is drawn into the fan near the shaft and then outward, and then spun around the housing to the outlet. Unlike an axial fan, a centrifugal fan blows air at right angles to the intake. Centrifugal fans produce more pressure for a given air volume than other types of fans, which made them ideal for ventilation systems like *Titanic*'s, where large volumes of air needed to be moved great distances.[7] They could be used either to move air into the ship, as for a supply duct, or to pull air out of the ship, as for an exhaust duct. For the latter, cowls were fitted to the exhaust outlet. This took advantage of the natural airflow past the cowl to reduce the air pressure at the outlet, thereby assisting the fan in ducting air out of the ship.

The centrifugal fans used on *Titanic* were manufactured by Davidson & Co. Ltd of Belfast. The name 'Sirocco' was this firm's trademark for this type of fan.[8] The majority of fans were at the upper terminal

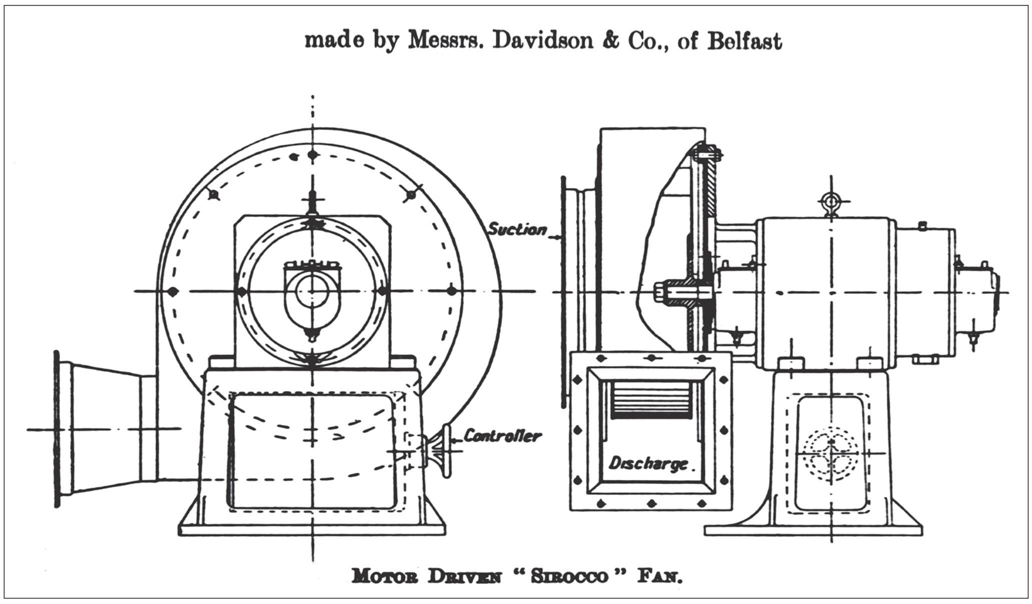

made by Messrs. Davidson & Co., of Belfast
Suction
Controller
Discharge
Motor Driven "Sirocco" Fan.

Fig. 19-15 **Sirocco Fan with Housing** – A typical Sirocco fan and housing assembly.

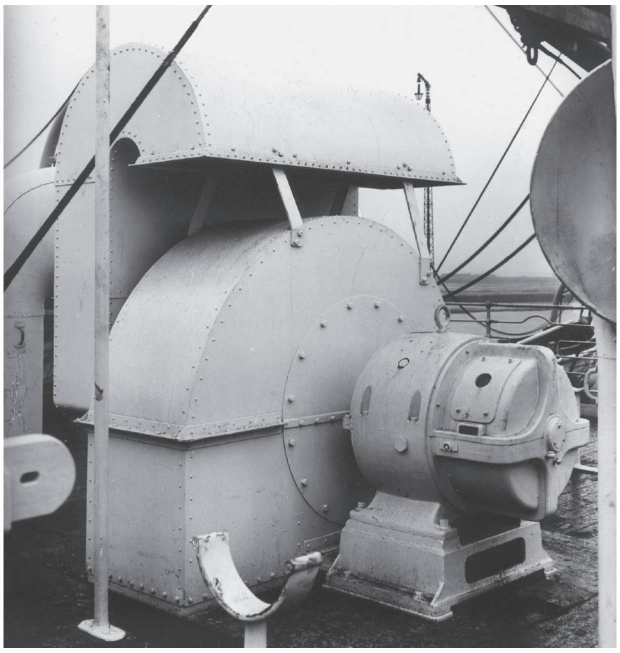


Fig. 19-16 **Swan-Neck Ventilator Head aboard *Ceramic*** – A Sirocco ventilator with a 'swan-neck' ventilator head, photographed aboard the White Star Liner *Ceramic c.*1913. *(*The Shipbuilder*/Authors' collection)*

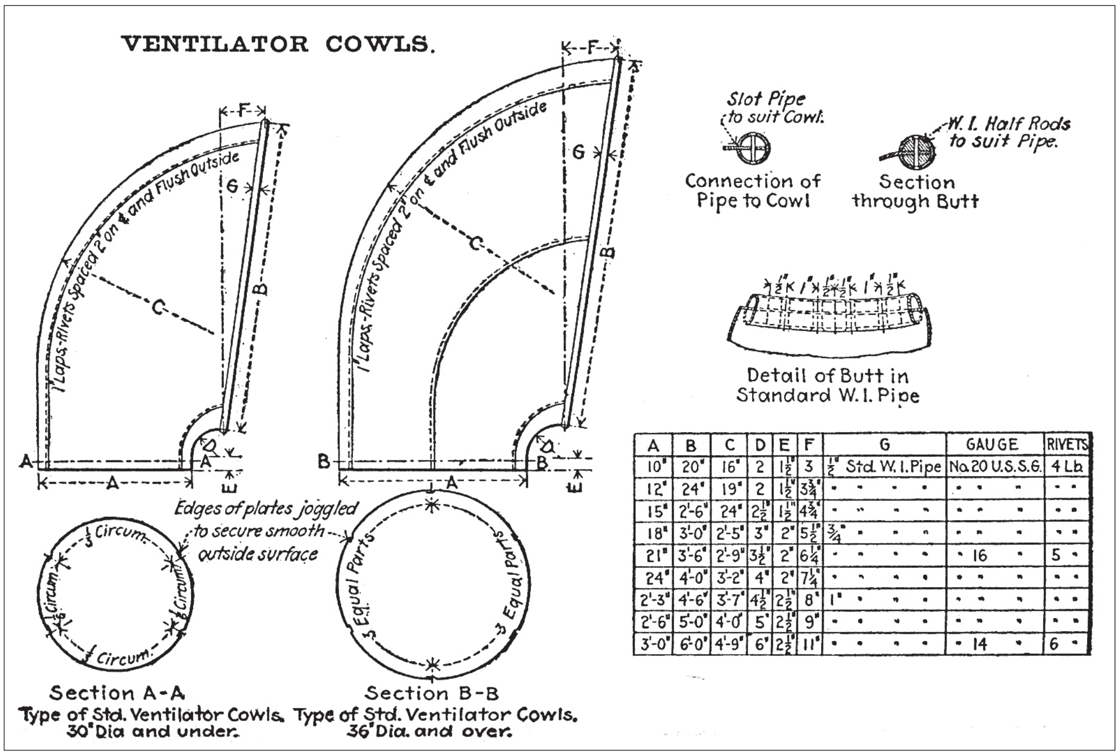
end of the exhaust vent trunks on or above the Boat Deck. The motors that powered the fans were fitted with controls that could be actuated remotely or at the ventilator. This permitted the speed of a given fan to be adjusted to suit the needs of that section of the ship that it was supplying with air. A fan that had to force air via its trunk down to the lowest deck – a distance of some 90ft – would require a higher rate of speed than one that had to serve the upper decks only. Additionally, the motors were designed so that the fan would maintain its selected speed regardless of the load placed on it.

The Sirocco fan was drum-like in appearance and had rectangular blades around its perimeter. The fans were placed in metal housings and were driven by various sizes of electric motors depending on the diameter of the fan and the intended volume of air it was required to move. The motors were manufactured by W. H. Allen, Son & Co. of Bedford to Harland & Wolff specifications.

On *Titanic*, the very largest Sirocco units were the stokehold ventilators with 55in diameter fans driven by 30BHP motors; the smallest Sirocco unit had a 10in diameter fan driven by a ¾BHP motor. The majority of Sirocco fans were either 35in (primarily for fresh air or warm air supply), 30in (for suction or hot air supply through thermotanks), or 20in (exclusively used with a cowl attachment to provide suction to remove foul air from below decks).

The appearance of the various fan housings differed in accordance with the ducting attachments required based on the function of each individual ventilator head. For fresh air supply, a 'swan-neck' intake head was attached to the center of the 35in diameter fan housing. Warm air supply fans were also 35in diameter models, which, with few exceptions, had no intake ducting attachments but instead drew air directly in through the large circular opening in the center of the fan housing. These fans were protected by guard railings to keep people away from the intake opening of the unit, as the suction created was quite powerful and could easily draw a person or their clothing into the unit. The Siroccos connected to thermotanks (devices by which supply air could be heated in cold weather) usually had no external intake ducting into the fan unless a 'swan-neck' duct was utilized.

Titanic's Sirocco fans were located around the ship in locations where the transmission of noise or vibration to the passengers would be minimized. On the Boat Deck, the fans were mounted on footings made from lengths of Z-bar or channel-bar riveted to the steel deck; the top flanges of these footings were fitted with studs positioned to correspond with the mounting holes in the base plate of the fan unit. Angle boundary bars were riveted to the deck around the footings to creating a rectangular space slightly larger than the overall size of the fan unit. Teak margin boards formed an outer periphery around the boundary bars, while the space within the margins was filled flush with Portland cement. Thin teak liners were inserted between the footings and the underside of the base plate to dampen the transmission of noise. In the case of the fans situated within below-deck rooms above passenger accommodations, they were further insulated from the steel by rubber or hair-felt packing interposed between the footings and decking. Whenever possible, the motors were installed with the armature shafts aligned fore and aft, so as to minimize gyroscopic action and reduce the wear on the bearings.


VENTILATOR COWLS.
F
G
C
B
A
D
E
1" Laps-Rivets Spaced 2" on ℄ and Flush Outside
Slot Pipe to suit Cowl.
W. I. Half Rods to suit Pipe.
Connection of Pipe to Cowl
Section through Butt
Detail of Butt in Standard W. I. Pipe
Edges of plates joggled to secure smooth outside surface
⅓ Circum.
3 Equal Parts
Section A-A
Type of Std. Ventilator Cowls. 30" Dia and under.
Section B-B
Type of Std. Ventilator Cowls. 36" Dia. and over.

A	B	C	D	E	F	G	GAUGE	RIVETS
10"	20"	16"	2	1½"	3	½" Std. W. I. Pipe	No. 20 U.S.S.G.	4 Lb.
12"	24"	19"	2	1½"	3¾"	" " " "	" " "	" "
15"	2'-6"	24"	2½"	1½"	4¾"	" " " "	" " "	" "
18"	3'-0"	2'-5"	3"	2"	5½"	¾" " " "	" " "	" "
21"	3'-6"	2'-9"	3½"	2"	6¼"	" " " "	" 16 "	5 "
24"	4'-0"	3'-2"	4"	2"	7¼"	" " " "	" " "	" "
2'-3"	4'-6"	3'-7"	4½"	2½"	8"	1" " " "	" " "	" "
2'-6"	5'-0"	4'-0"	5"	2½"	9"	" " " "	" " "	" "
3'-0"	6'-0"	4'-9"	6"	2½"	11"	" " " "	" 14 "	6 "

Fig. 19-17 **Standard Cowl Dimensions** – These illustrations show the configuration of a common cowl vent. The table and gauge specifications are based on a US source.

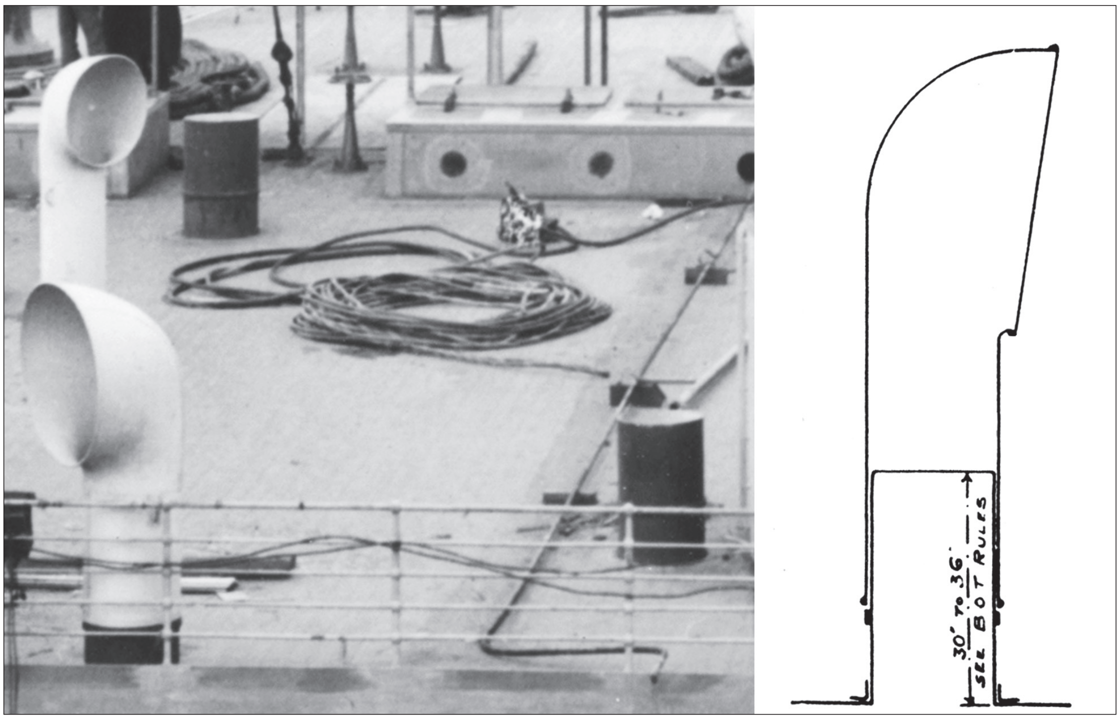

30" to 36" SEE BOT RULES

Fig. 19-18 **Unshipped Cowls** – At left, two unshipped cowls on *Olympic* during construction. The coaming upon which the cowls were shipped appear as short, black cylinders on the deck. At right, a plan view of a cowl showing the Board of Trade requirements for the coamings. *(H&W/Authors' collection)*

VENTILATOR HEADS

A great variety of ventilator heads were in use on ships of *Titanic*'s era. Originally the cowl and the mushroom were the most universally adopted for ordinary purposes where simplicity and efficiency were principal design considerations. In addition to these, numerous patent ventilator heads of one form or another were utilized on the *Olympic*-class liners.

Cowl ventilator heads

Cowl ventilator heads, the appearance of which were described earlier, were readily visible on *Titanic*'s Boat Deck and Poop Deck, with only one being located on the Forecastle Deck. The cowls on the Poop and Forecastle Decks appear to be stand-alones without visible housings or motor attachments. However, only a few of these were truly passive ventilators; in most cases they were connected to fans below decks.

Cowl heads had handles whereby the direction of the mouth opening could be changed. This was an asset when the ship was stopped and the prevailing airflow was not necessarily from forward. As most cowl vents were employed as uptake ventilators, they functioned most effectively when the cowl head was turned to face away from the prevailing airflow or wind over the deck. For this reason, the cowls fitted to *Titanic* were most often seen facing aft or at a slight angle to the centerline.

Cowl ventilators were constructed of galvanized sheet steel with the thickness usually specified in wire gauge. The head, or cowl, was composed of segments hammered to shape and riveted together. The lip was strengthened by a stout beading. The vertical, cylindrical section of the cowl was fitted over a similar section of lesser diameter that was fixed to the deck. This fixed portion, called the coaming, was made of steel plating rolled into a tube and riveted with an inside strap. The upper part of the ventilator, when shipped over the coaming, rested upon an iron ledge on the outside of the coaming on the toe of the deck angle. However, it was preferable to provide a special bearing ring in order that it could be rotated with less effort. The coaming had to stand at least 30in above the deck to minimize the chance of a downpour of water if the deck was awash, because the cowl and the coaming did not fit together tightly enough to form a watertight seal. Cowls were also designed to be unshipped and stowed away in severe weather. Covers for the coamings were provided for such instances; these consisted of wooden plugs or canvas. Covers to be placed over the openings of the cowls in certain circumstances were also carried

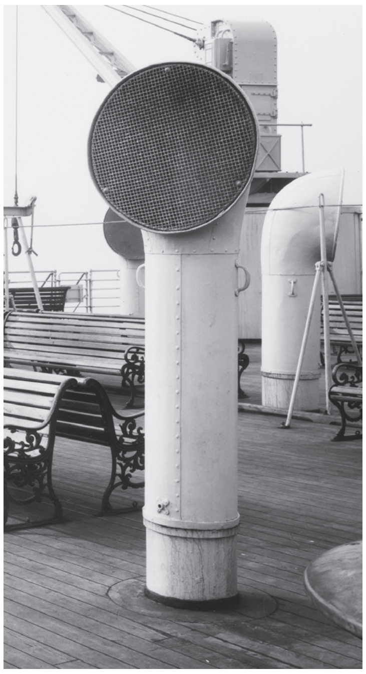


Fig. 19-19 **Poop Deck Cowl with Screen** – A screened cowl on *Olympic*'s Poop Deck. Behind the wire mesh screen is a reinforcing cross-bar. *(Daniel Klistorner collection)*

Owing to the corrosive nature of salt air and salt water, cowls were subject to internal corrosion which could go unseen for long periods. On older ships, some cowl tubes were seen wasted through with holes. This represented a serious danger as the impact of boarding seas washing across a deck in heavy weather could be sufficient to carry a ventilator coaming away, perhaps unobserved if at night, with solid water on the deck gaining entry to deck spaces below. As vessels were known to have been lost from deteriorated cowl tubes, it was required, as a condition of freeboard assignment[9] that ventilator coamings be strongly made, of steel at least $^6/_{20}$in thick, riveted to deck plating not less in thickness than the coaming, or thickened by a doubling plate.

If the deck beams were two frame spaces apart, a fore-and-aft carling was required to be fitted between the beams on each side of the ventilator. The angle connecting the coaming to the deck was required to be thicker than the coaming. If it was riveted first to the tube, the camber of the deck had to be taken into account. If the deck was of wood alone, deck plating had to be provided beneath the deck planks in way of the ventilator.

Because of the large size of *Titanic*'s cowls, they had tubular stays fitted radially across their mouths; these provided support for wire mesh guards to prevent objects being thrown or drawn down into the fans. (The vertical tubes of the cowls were further protected within their throats with a second fitting of wire mesh.) All cowl vents were screened over their mouths, with only three known exceptions: the two cowls on the top of the reciprocating engine casing and one to starboard of the No.4 Funnel on the raised roof of the First Class Smoke Room. These anomalies are a

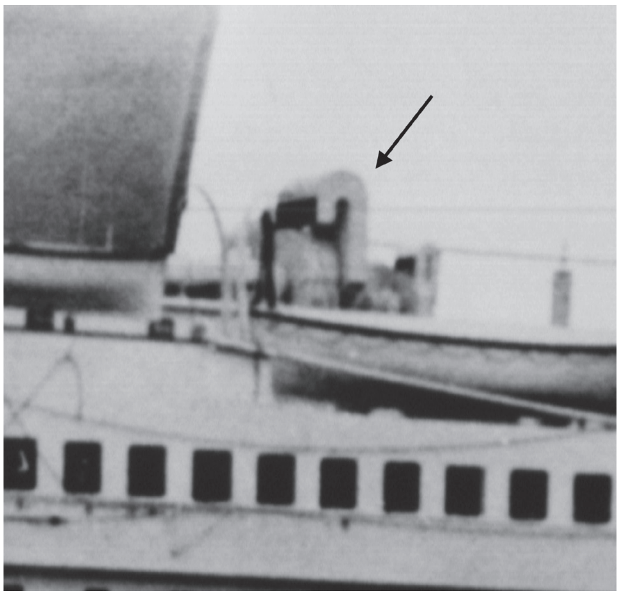


Fig. 19-20 **Swan-Neck Ventilator Head** – A swan-neck ventilator head as seen on *Titanic*. There were many variations of this form of ducting, but this design was generally called a 'swan-neck' because of its physical appearance.

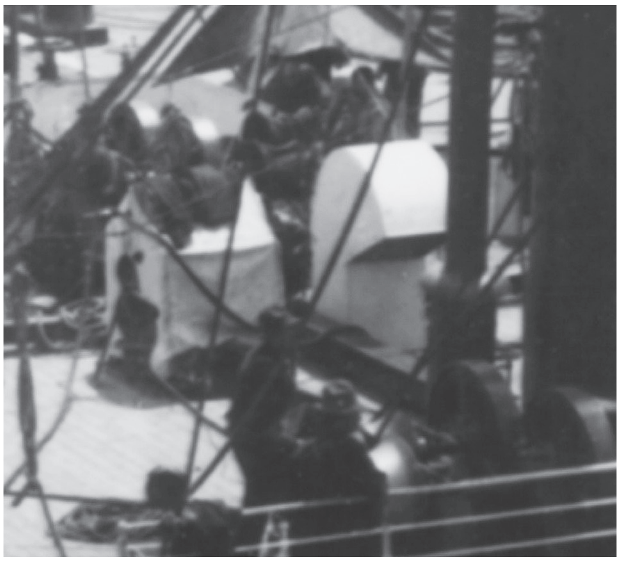


Fig. 19-21 **Swan-Neck Ventilator Head** – Another type of swan-neck ventilator head as seen on *Olympic*. This one was located on the Forecastle Deck just forward of the mast. These are sometimes referred to as 'foul weather' vents by *Titanic* enthusiasts.

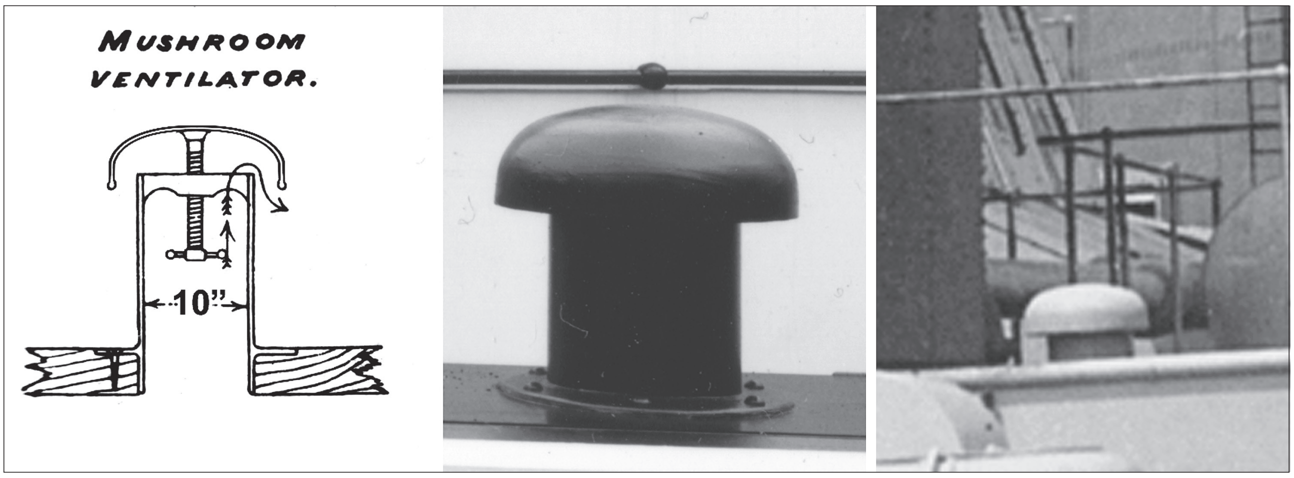


Fig. 19-22 **Mushroom Ventilator Head –** These were common shipboard fittings, as seen in the general illustration at left. At center, a mushroom ventilator head from another White Star Line ship of the era. At right, a mushroom ventilator head on the roof of *Olympic*'s No.3 Funnel deckhouse on the port side. *(Illustration from* Practical Shipbuilding*; center image authors' collection; right image Peter Davies-Garner collection)*

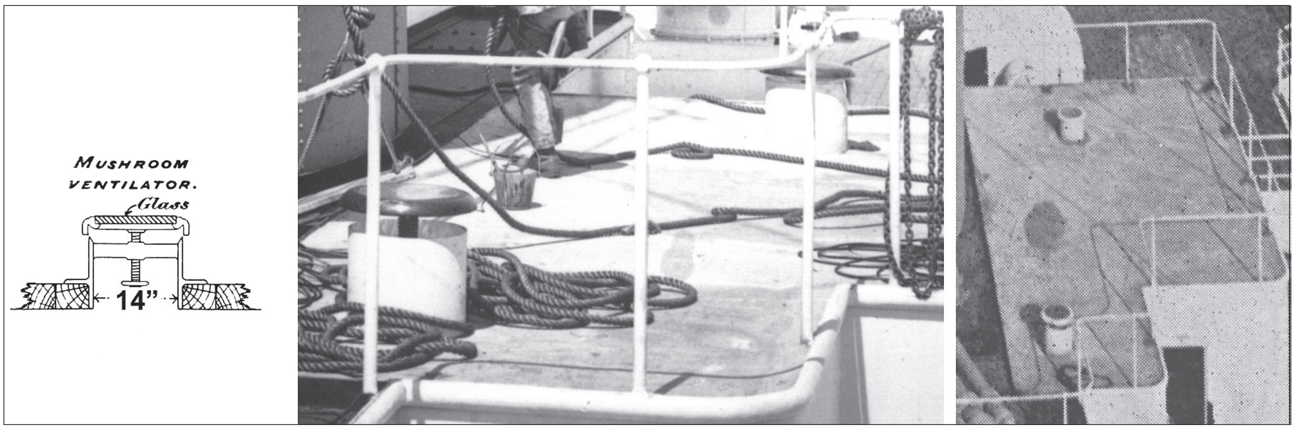


Fig. 19-23 **Mushroom Ventilator with Skylight Glass** – The center glass was reinforced with embedded wire mesh. These images are from the roof over *Olympic*'s Officers' Mess and Pantry; the diagrammatic form gives another perspective. *(Both images authors' collection)*

mystery – an optical illusion in the old photographs is possible but unlikely. In black-and-white photographs, this wire mesh fastened to the cowl mouths, together with the inside being in shadow, created the illusion that the insides were painted some darker color, often interpreted as gray or red; in reality, the insides of *Titanic*'s cowls were painted white.

Swan-neck ventilator head

There were a number of ventilator heads with a wide rectangular cross-section. They had a unique appearance and were commonly referred to as 'swan-neck' ventilators due to the curves associated with their intake ducting. Swan-neck ventilator heads could be seen surrounding the boiler casings; as they were intakes for supply ducting, they were paired with Sirocco fans. The intake ducts had forward, outboard or downward facing openings, and as with many of the ventilators on the uppermost deck, the swan-neck ventilator heads were fitted with protective screens to keep debris out of the fans.

Mushroom ventilator heads

The mushroom ventilator, befitting its name, gave the appearance of a mushroom with a flattened top. This type was largely employed for ventilating cabin and deckhouse spaces on the Boat Deck and can be seen in photographs of the roofs of *Titanic*'s deckhouses. Mushroom ventilators were somewhat inefficient, especially as a supply ventilator, and were seldom used for this purpose. The mushroom ventilator acted as an active uptake because, as the wind blew past the base of the hood, it created an area of low pressure on the leeward side; this, in turn, induced an upward air current within the ventilator. The updraft could be regulated by screwing the hood up or down and, as this overlapped the open end of the tube, it prevented the entrance of rain or spray. If the deck overhead was awash with water, the hood could be screwed down tightly, although

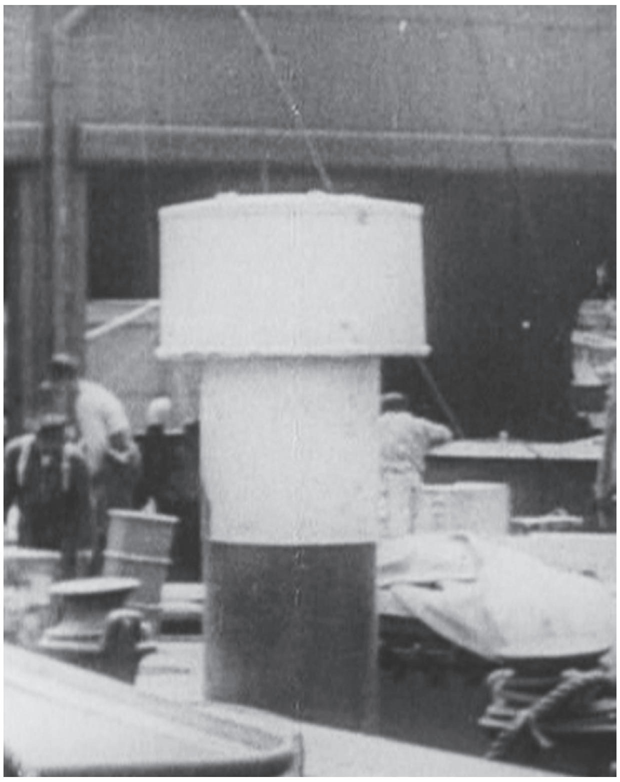


Fig. 19-24 **French-Type Ventilator Head** – The French ventilator head in *Olympic*'s forward Well Deck between the Nos 2 and 3 Hatches.

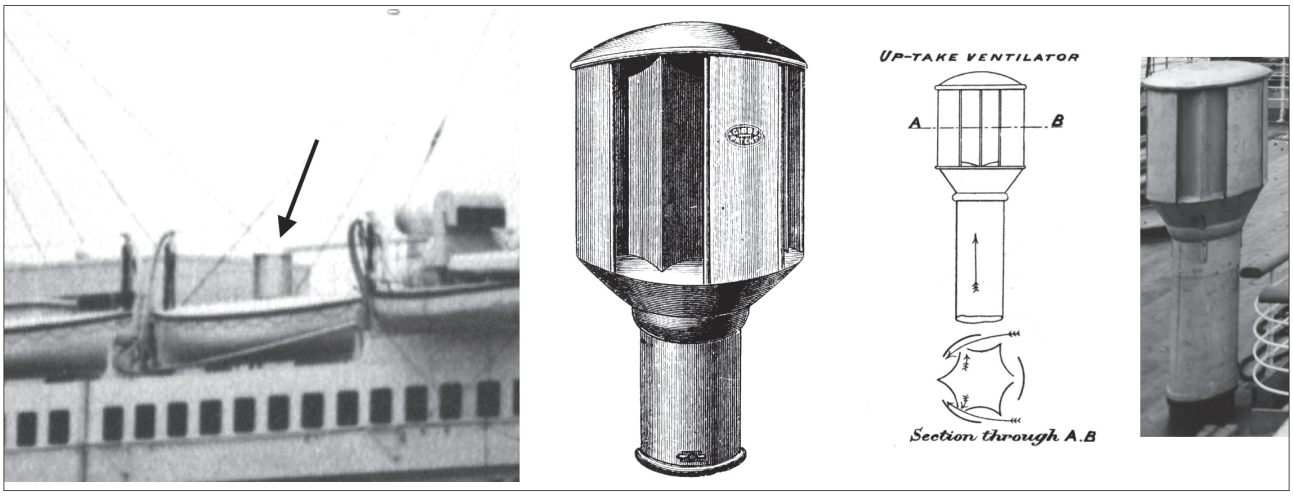


Fig. 19-25 **Gibbs Extractor** – On *Titanic*, this design was used on the deckhouse roof over the Elevator Machinery Room on the Boat Deck as seen in the left image. It was also used on the port and starboard sides of the roof over the aft Second Class Entrance on the Boat Deck and in the after Well Deck between the Nos 5 and 6 Hatches. The image at far right shows one at the aft end of *Olympic*'s A Deck, which was replaced with a 10in Sirocco fan early in her career. The illustration shows how this ventilator head functioned to passively extract air. *(Far left and far right images authors' collection; left center drawing authors' collection; right center drawing from* Practical Shipbuilding*)*

mushroom ventilators were not intended to be used in any areas where a significant amount of water could be shipped on board.

Another type of mushroom ventilator was provided with the hood having a circular rim framing a strong pane of wire-reinforced glass to admit light; this allowed it to function as a skylight as well. The lid could be screwed down tightly against the coaming by the use of a threaded shaft and hand wheel if necessary. There were three of this type fitted: one on the roof over the Marconi Silent Room on the Officers' Quarters deckhouse roof, and two over the Officers' Mess on the starboard side of the No.3 Funnel, each being approximately 14in in diameter. All other mushroom ventilators were 10in in diameter.

Because mushroom ventilators communicated directly to the outside through the overhead of a compartment, they were useful in ventilating interior compartments on the uppermost deck which, because of their location, could not be provided with sidelights.

Gibbs extractor

Manufactured by the company of John Gibbs & Son of Liverpool, the Gibbs extractor consisted of a vertical cylindrical base topped by a drum-shaped cover with large vertical openings in the sides. Inside the cover were a number of curved vertical strips of metal with gaps or slots between them. The design was such that wind would pass through an opening in one side of the cover and out the other side, at the same time blowing across the gaps between the curved vertical pieces. This induced an upward current of air in the tube. These Gibbs extractors, of which there were four on *Titanic*, were associated with ventilation of elevator shafts, except for one located centrally between the Nos 5 and 6 Hatches in the after Well Deck.

French ventilator head

The French-top ventilator head was used in one location aboard *Titanic*, in the center of the forward Well Deck. In appearance it resembled a wide drum placed upside down over the top of a tall vertical column, and was constructed much the same way, with struts holding the drum-like section above the opening of the column so as to permit the passage of air. This particular ventilator was used as an intake in this instance. The openings and air passage of the French ventilator head were made of ample size in order to reduce air resistance. This type of ventilator head, owing to its location, was designed to withstand spray and large amounts of water thrown directly against it.

Fyfe ventilator head

These ventilator heads were designed along the same lines as the Gibbs extractor, except the upper covering section had a curved, rounded top instead of sharp corners. This, along with its much smaller size, made it ideal for use in areas frequented by passenger traffic. As it was not used in locations that were subject to more than rain

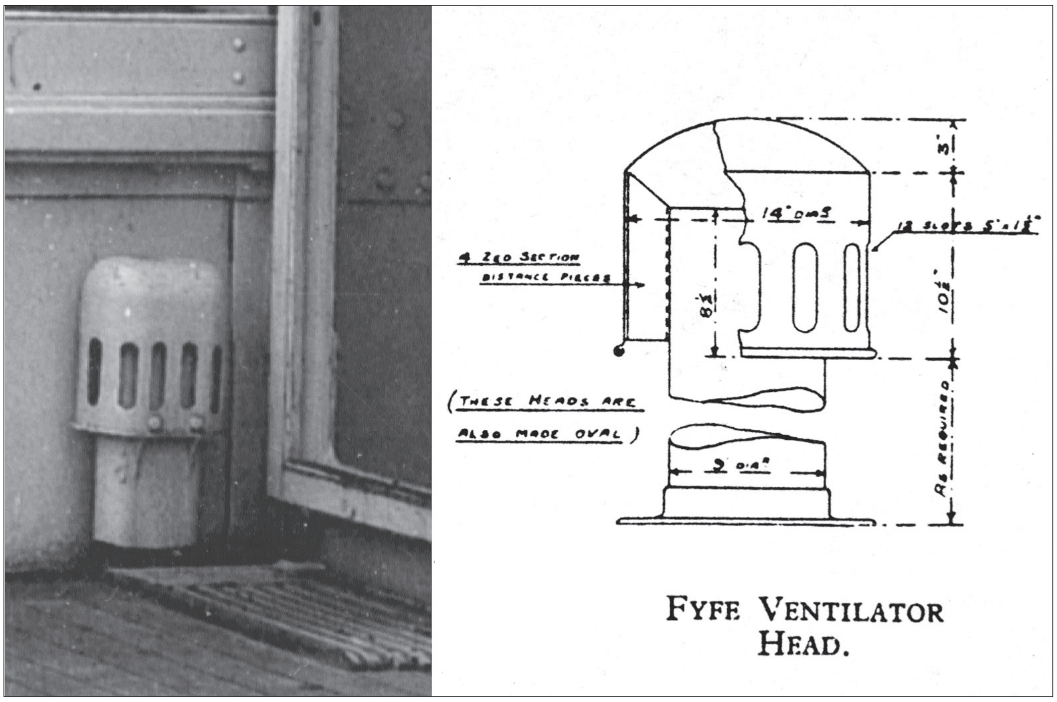


Fig. 19-26 **Fyfe Ventilator Head** – A Fyfe-type ventilator head on *Olympic*, with a partial section drawing illustrating the features typical of this type. This design was seen at the after end of A Deck tucked behind the benches, and (as shown at left) in the after port corner of the Boat Deck's raised roof over the Lounge, next to the door for the stairs leading to A Deck. *(Left image Authors' collection; illustration from* Practical Shipbuilding*)*

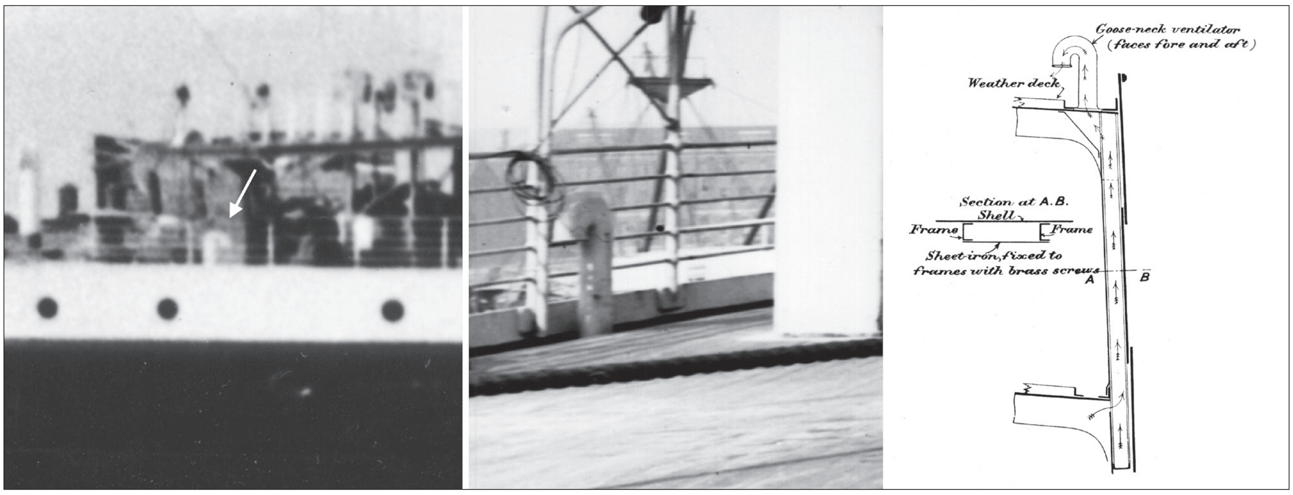


Fig. 19-27 **Gooseneck Ventilator** – A gooseneck ventilator as seen on *Titanic* (left) and *Olympic* (center). The illustration at right shows how it was fitted aboard ship. *Titanic*'s goosenecks of this type had the openings facing aft, while *Olympic*'s faced forward. These goosenecks, which were located both port and starboard under the ends of the Docking Bridge on the Poop Deck, ventilated the area immediately below on D Deck. *(Both images authors' collection; illustration from* Practical Shipbuilding*)*

and wind-blown spray, it had elongated vertical slots in the cover to better admit air. The ones on *Titanic* were oval-shaped when viewed from above, which reduced the width and permitted installation in tight spaces such as near a doorway. A few Fyfe-head ventilators were used on *Titanic* at the after end of A Deck, cleverly hidden behind benches. A separate Fyfe-head ventilator could be found on *Olympic* at one point in her career on the port side of the Boat Deck just aft of the raised roof over the First Class Lounge. However, a corresponding Fyfe has yet to be verified on *Titanic* in this location.

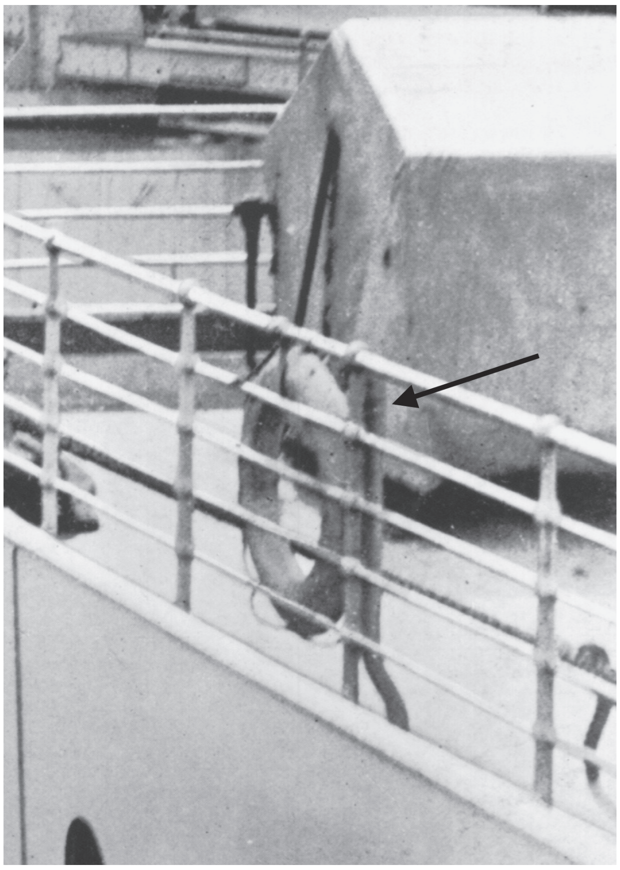


Fig. 19-28 **Gooseneck Ventilator for Tanks** – A small gooseneck ventilator neatly concealed alongside one of the railing stanchions of the Poop Deck. These vents allowed air to be drawn into or expelled from the double-bottom tanks. Other pipes like this were fitted along the inboard sides of the Well Deck bulwarks.

Gooseneck ventilators

Gooseneck ventilators also served as uptakes but their design did not induce as much draft as a mushroom ventilator. Goosenecks were largely employed for ventilating storerooms and other small spaces below. When conditions were such that the decks were awash or likely to become awash with water, the open end was plugged up or covered with canvas, unless the vents installed were of the type fitted with automatic float valves to seal the openings.

Mushroom and gooseneck ventilators were usually of cast iron. Two goosenecks can be seen flanking the Docking Bridge on the Poop Deck; these were of the type fitted with float valves. Smaller gooseneck ventilators were fitted along the inboard face of the bulwarks in the well decks. These devices were smaller in diameter than those seen for compartment ventilation, and were for venting the double bottom tanks, although in a different sense. Water tanks required ventilation for the purpose of equalizing pressure, so that as the tank filled the air above the water surface would be expelled, or drawn in as the tank was emptied.

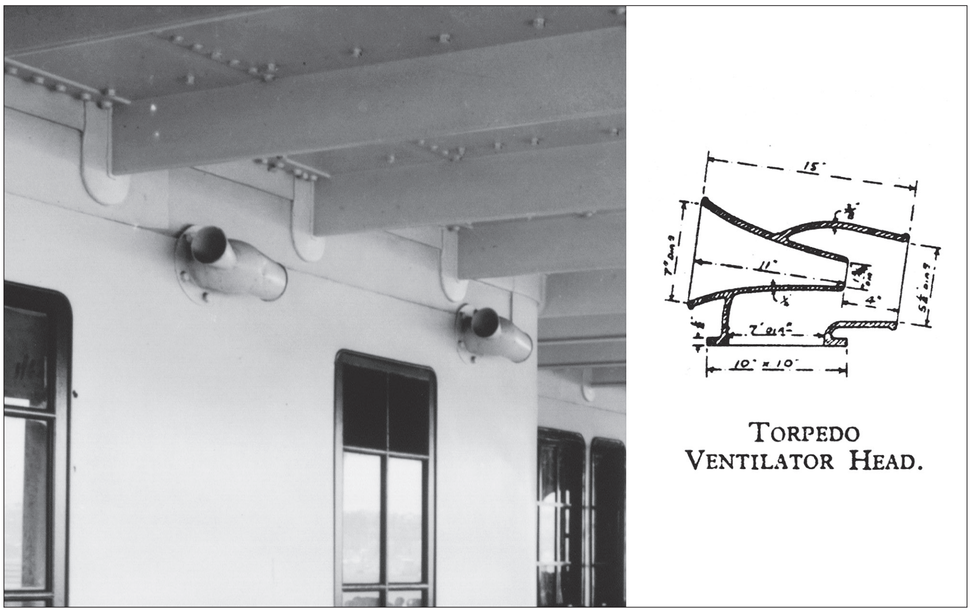


Fig. 19-29 **Torpedo Ventilator Head** – This is a ventilation device which may not have been used aboard *Titanic*. This example is from *Olympic* in 1911 and was located along the starboard Second Class B Deck Promenade on a bulkhead outside the *à la carte* Restaurant Galley. On *Titanic* both this Galley and the Restaurant extended out to the side of the ship.

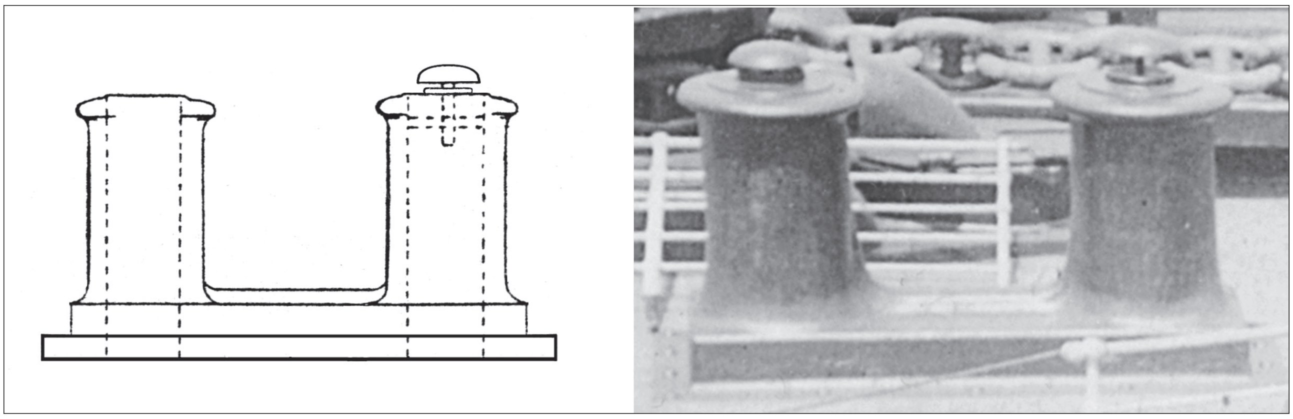


Fig. 19-30 **Ventilating Bollard** – At left, an illustration of a typical pair of ventilating bollards. At right, a similar set on *Olympic*'s Forecastle Deck. Although these are properly called 'bitts,' the original Harland & Wolff terminology for these has been used in this chapter. *(Left image* Practical Shipbuilding*; right image authors' collection)*

Torpedo ventilators

Olympic also made use of a ventilator head alternately called a torpedo or trumpet ventilator, fastened along the exteriors of bulkheads to act as an exhaust ventilator. Torpedo ventilators were used extensively on railways, and resembled a cylinder mounted horizontally atop a vertical stack. When mounted atop the roof of a railway car or caboose in a fore-and-aft direction, the wind would pass through the cylindrical section when the train was in motion, thereby inducing an updraft through the stack. *Olympic*'s were not true torpedo vents, and resembled instead a cowl vent without the cylindrical section, with a trumpet-shaped fitting inserted into the elbow of the cowl, hence the more correct name 'trumpet ventilator'. The design was such that air would pass through the narrowing flare of the trumpet and then exit through the cowl mouth at the opposite end at a greater velocity than when it entered, thereby drawing air out. Because of this, ventilators of this type functioned best when placed to take maximum advantage of the stream of air provided by the ship's forward motion. Although it is possible that torpedo ventilators of this type were used on *Titanic*, no evidence has been found of any yet; it is possible that owing to the sheltered locations in which they were employed on *Olympic* they were less successful than intended and therefore were not duplicated on *Titanic*.

Ventilating bollards

The mooring and tow bollards[10] on the Forecastle and Poop Decks were designed to also serve as ventilators by utilizing their hollow shafts as air trunks, topped with mushroom-style caps instead of flat steel discs. The caps atop the bollards were attached to internal shafts that allowed them to be raised or lowered from within. These fittings

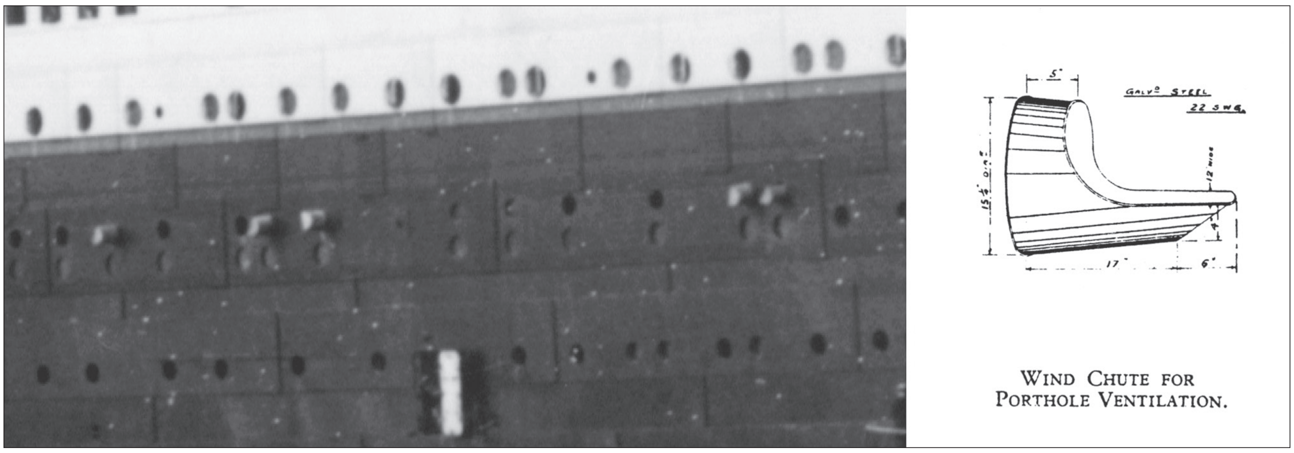


Fig. 19-31 **Wind Scoop** – Though already covered in the chapter with the sidelights, another view is presented here showing wind scoops in use aboard the *Olympic*. The wind scoop depicted in the accompanying drawing, though of a somewhat different design, illustrates one of the types commonly found aboard ships in the era of the *Olympic*-class liners. *(Image and illustration from authors' collection)*

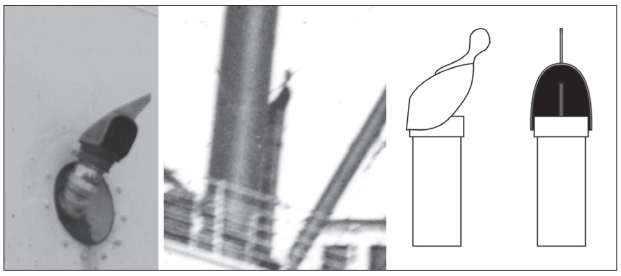


Fig. 19-32 **Crew Galley Flue** – At left, a contemporary swiveling cowl extending out of the porthole of an unidentified ship. At center, *Titanic*'s Crew Galley flue. At right, a drawing depicting the design of this flue on *Titanic*. These types of rotating cowl heads were very common in the era, and are still in use today. The ventilation of this galley must have caused some headaches for Harland & Wolff because *Olympic*'s original flue did not look like this, and it appears that the design changed quite a bit through her career.

were merely used for natural exhaust, as the mushroom heads were not wide enough to create the low pressure necessary at the opening to draw air upwards. The bollards in the Well Decks were not of the ventilating type.

Sidelights

Titanic's sidelights and skylights were integral elements of her ventilating system as they were intended to provide air as well as light. In some instances, they were made to swivel so that a portion of the glass with its frame projected beyond the side of the vessel. With the motion of the vessel, and depending on the angle to which the glass was adjusted, a flow of air could be directed into or extracted from the room. Another device known as a wind scoop was provided for the common porthole without pivoting glass frames. These were welcome additions to the ventilation of a compartment, most especially in midsummer. As with the pivoting sidelights, they could be positioned direct air into the room or, by turning the scoop to face opposite the breeze, they could be made to draw stale air out through the porthole.

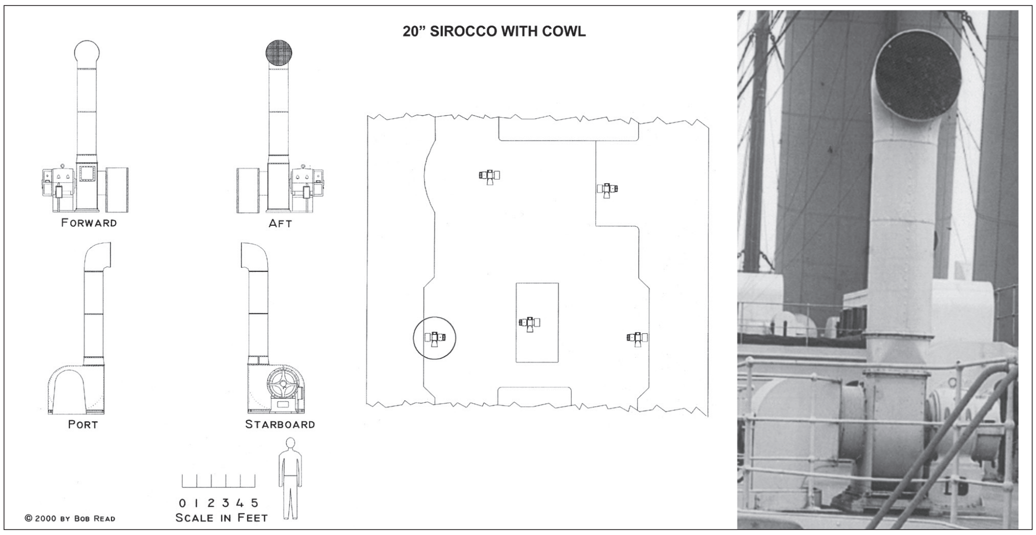


Fig. 19-33 **Cowl Vent on 20in Sirocco Fan** – A typical 20in Sirocco with a cowl fitting. The image to the right shows a ventilator of this type fitted on *Olympic*. *(Illustrations by Bob Read; image from Peter Davies-Garner collection)*

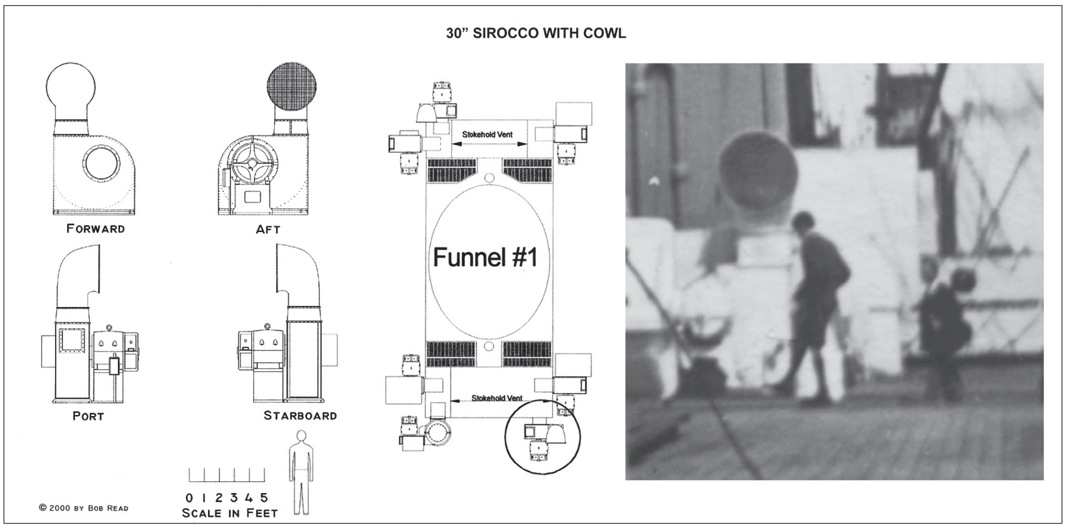

30” SIROCCO WITH COWL
Forward
Aft
Port
Starboard
Stokehold Vent
Funnel #1
Stokehold Vent
0 1 2 3 4 5
Scale in Feet
© 2000 by Bob Read

Fig. 19-34 **Cowl Vent on 30in Sirocco Fan** – A typical 30in Sirocco with a cowl fitting attached directly to the fan trunk casing aft of the No.1 Funnel, as seen on *Olympic. (Illustrations by Bob Read; image from Peter Davies-Garner collection)*

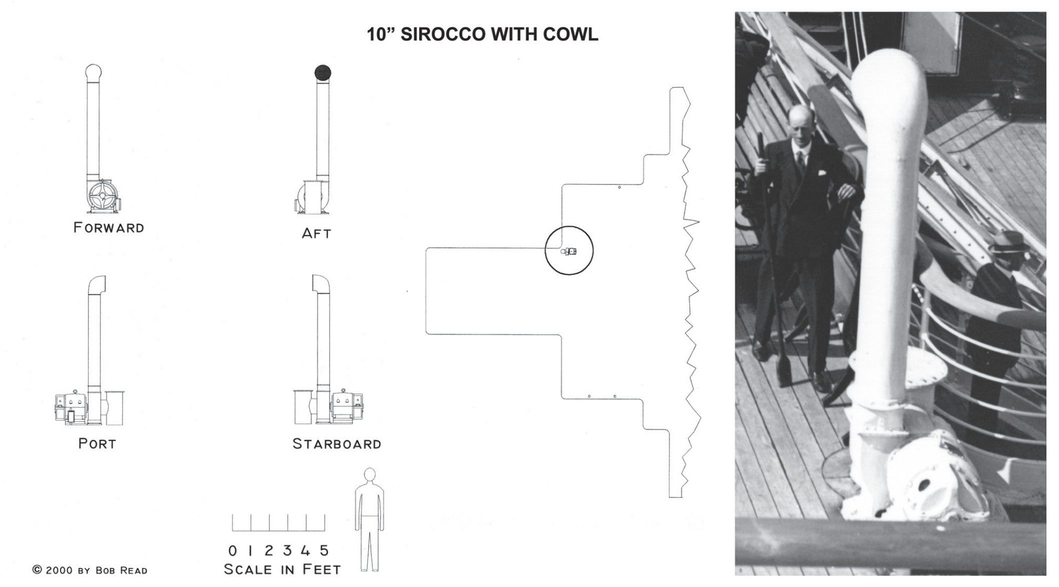

10” SIROCCO WITH COWL
Forward
Aft
Port
Starboard
0 1 2 3 4 5
Scale in Feet
© 2000 by Bob Read

Fig. 19-35 **Cowl Vent on 10in Sirocco Fan** – The only 10in Sirocco fitted with a cowl on *Titanic* and *Olympic*. This one was located at the after end of A Deck on the port side. This example is from *Olympic* and shows the fan housing connected to a coaming much like those shown beneath the cowl vents on the Poop Deck. The reason for this is due to the fact that *Olympic* was originally fitted with a Gibbs extractor in this location, but was retrofitted with a motorized suction fan early in her career. *Titanic*, on the other hand, was built with a fan in this location. With this said, the illustration is indicative of *Olympic*'s design, as *Titanic* may have had an regular duct through the deck as seen with other cowl vents on the ship. *(Illustrations by Bob Read; image from authors' collection)*

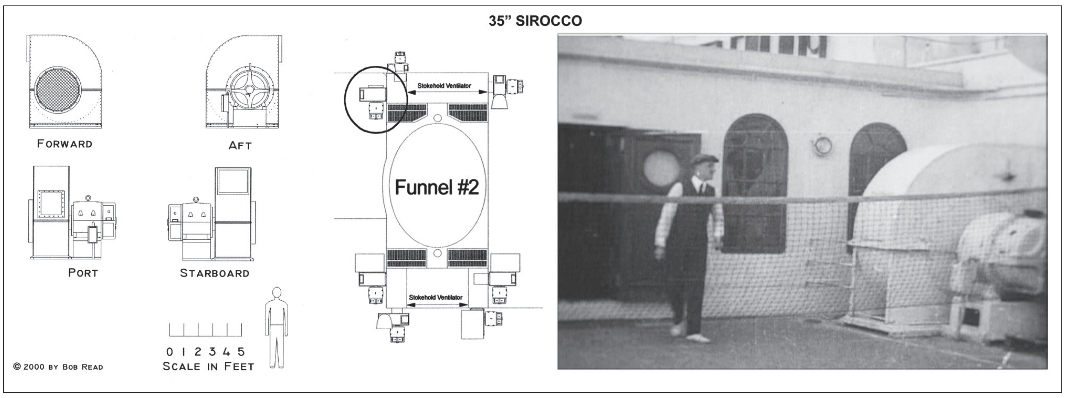

35” SIROCCO
Forward
Aft
Port
Starboard
Stokehold Ventilator
Funnel #2
Stokehold Ventilator
0 1 2 3 4 5
Scale in Feet
© 2000 by Bob Read

Fig. 19-36 **35in Sirocco Fan** – A typical 35in Sirocco fan. Located on the port side of *Olympic*'s Boat Deck immediately abaft the First Class Entrance and abreast of the casing beneath the No.2 Funnel, this unit delivered air through a fan trunk which supplied heated air on the warm-air system. The intake opening for the fan housing faces the corner of the deckhouse, and a three-rail guard fence has been installed to keep people away from the opening. *(Illustrations by Bob Read; image from authors' collection)*

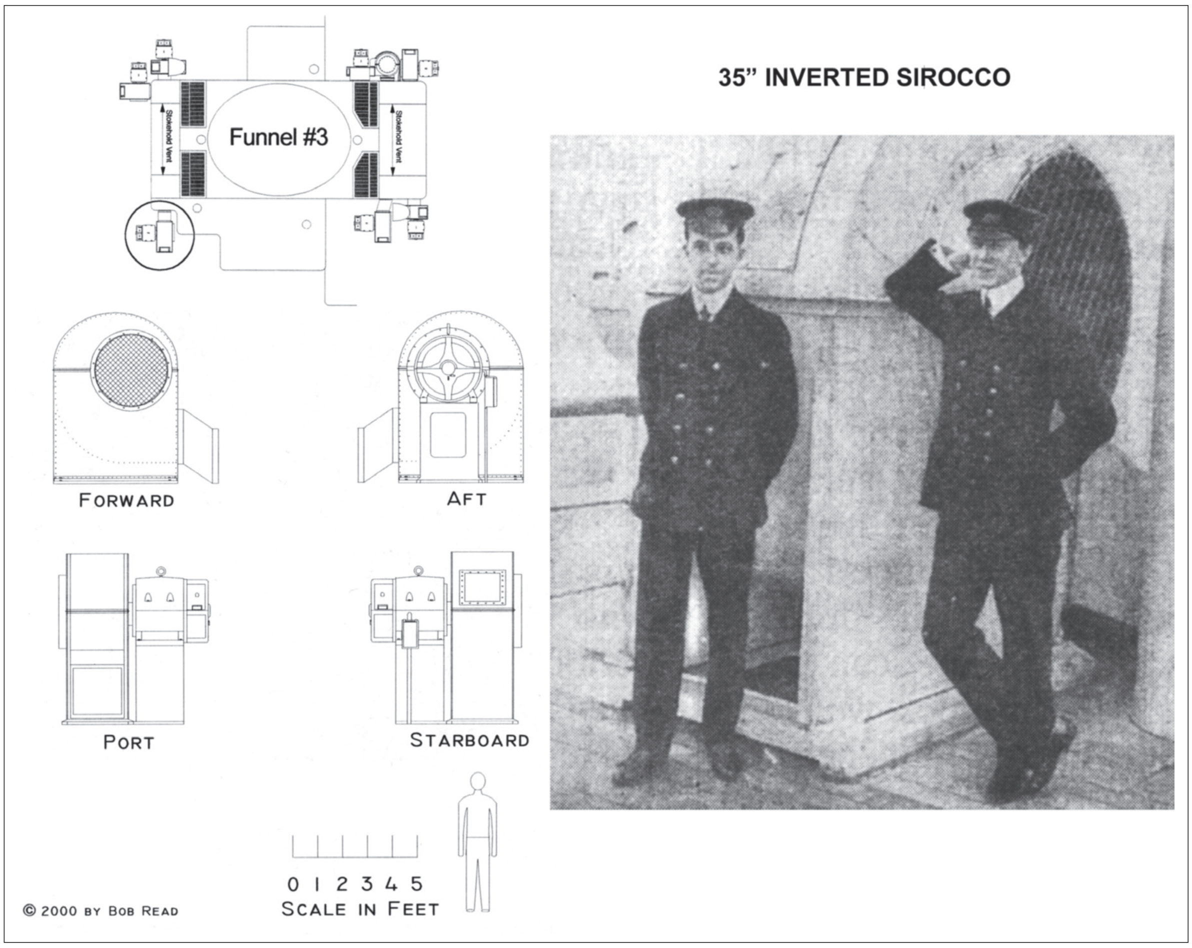

35" INVERTED SIROCCO
Funnel #3
Stokehold Vent
Stokehold Vent
FORWARD
AFT
PORT
STARBOARD
0 1 2 3 4 5
SCALE IN FEET
© 2000 BY BOB READ

Fig. 19-37 **Variation of 35in Sirocco Fan Installation** – Here was one variation of the 35in Sirocco that was a bit odd. This installation, seen here on *Olympic* with Marconi operators E. J. Moore and A. Bagat, was inverted. The reason for this may have had to do with the machinery for the Officers' Galley Pantry service hoist which was located within the casing right behind where this fan was connected. This trunk also supplied heated air on the warm-air system. *(Illustrations by Bob Read; image from authors' collection)*

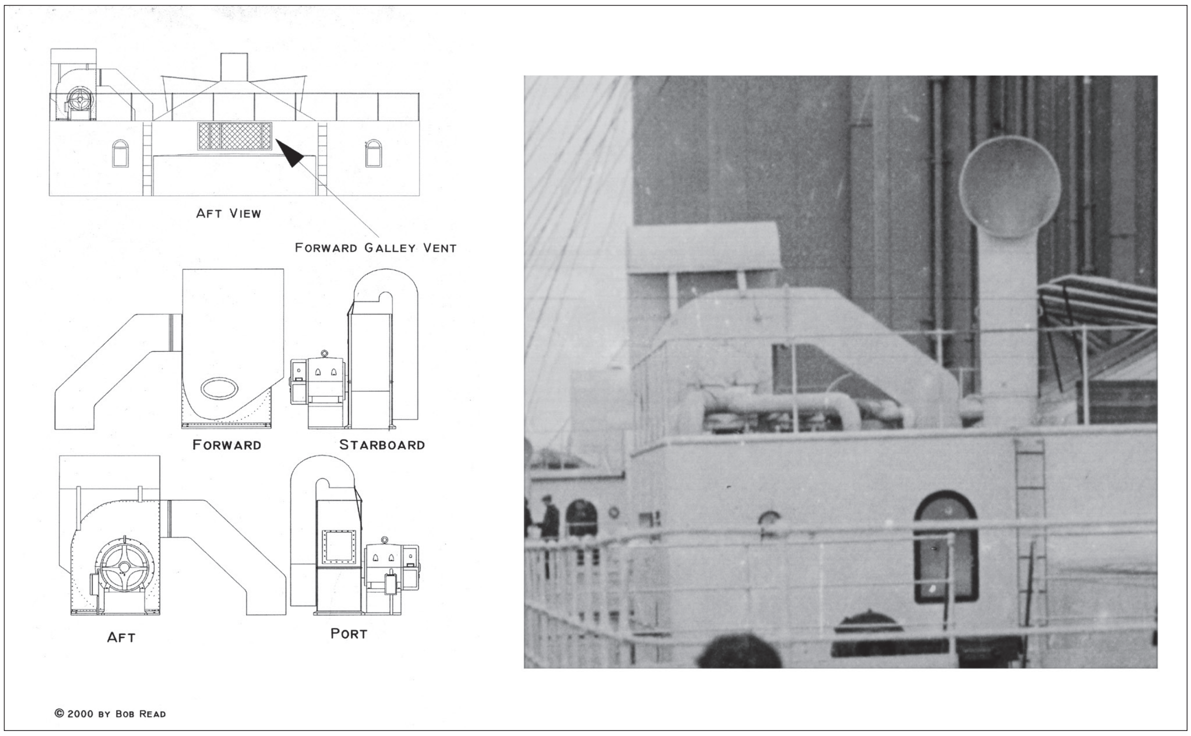

AFT VIEW
FORWARD GALLEY VENT
FORWARD
STARBOARD
AFT
PORT
© 2000 BY BOB READ

Fig. 19-38 **Tank Room Fan** – Probably the most elaborate ducting fitted to a Sirocco fan on *Titanic* was that found above the port-side Tank Room. *(Illustrations by Bob Read; image from authors' collection)*

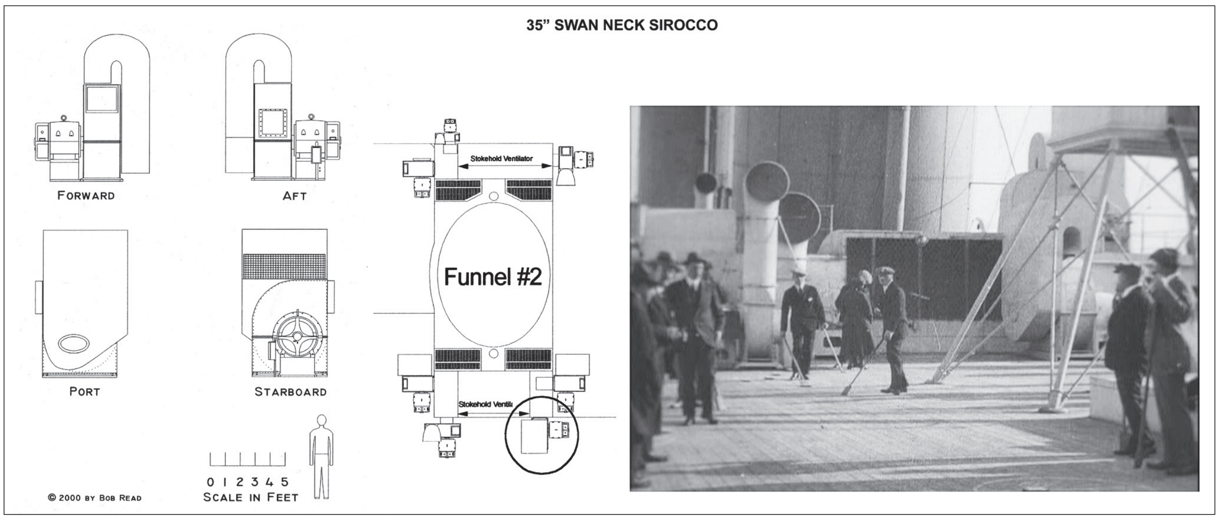

35" SWAN NECK SIROCCO
FORWARD
AFT
PORT
STARBOARD
Stokehold Ventilator
Stokehold Ventil
Funnel #2
0 1 2 3 4 5
SCALE IN FEET
© 2000 BY BOB READ

Fig. 19-39 **Swan-Neck Ventilator Head on Sirocco Fan** – One of *Olympic*'s swan-neck ventilator heads fixed to a Sirocco fan at the after end of the No.2 Funnel casing. *(Illustrations by Bob Read; image from authors' collection)*

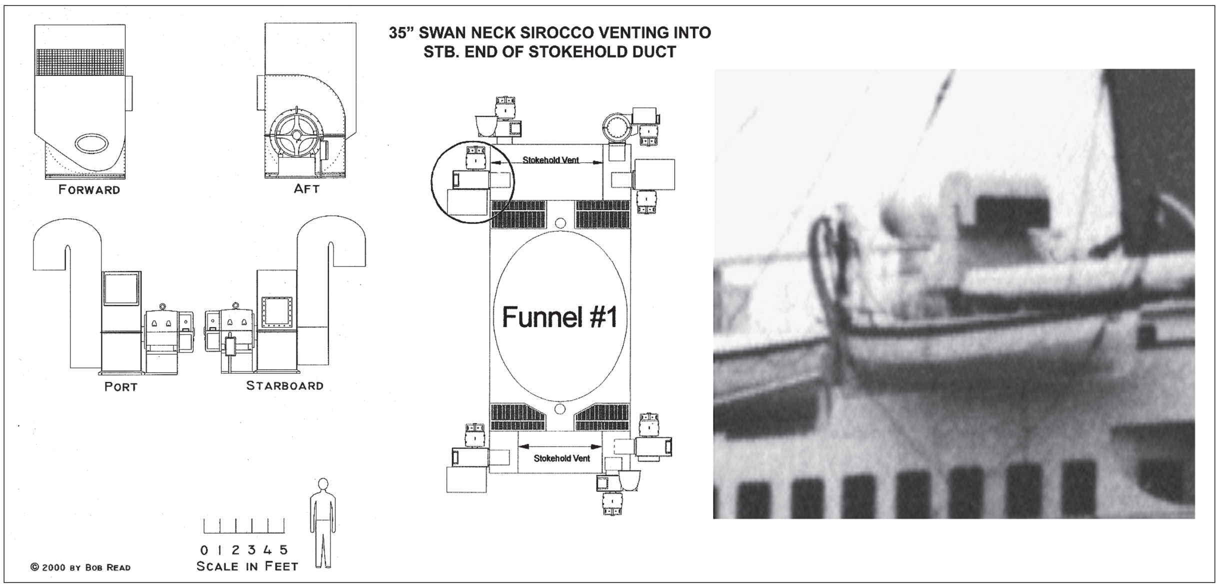

35" SWAN NECK SIROCCO VENTING INTO
STB. END OF STOKEHOLD DUCT
FORWARD
AFT
PORT
STARBOARD
Stokehold Vent
Stokehold Vent
Funnel #1
0 1 2 3 4 5
SCALE IN FEET
© 2000 BY BOB READ

Fig. 19-40 **Swan-Neck Ventilator Head** – Another variation of a swan-neck ventilator head, this one fitted to a fan over the Officers' Quarters deckhouse on *Titanic*. *(Illustrations by Bob Read; image from authors' collection)*

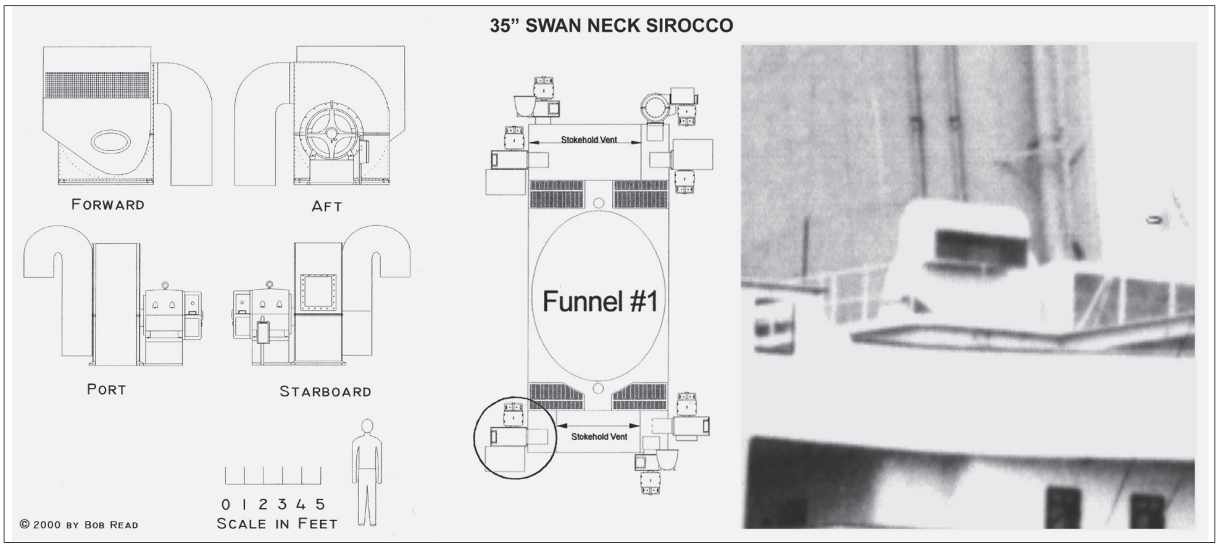

35" SWAN NECK SIROCCO
FORWARD
AFT
PORT
STARBOARD
Stokehold Vent
Stokehold Vent
Funnel #1
0 1 2 3 4 5
SCALE IN FEET
© 2000 BY BOB READ

Fig. 19-41 **Swan-Neck Ventilator Head**. *(Illustrations by Bob Read; image from authors' collection)*

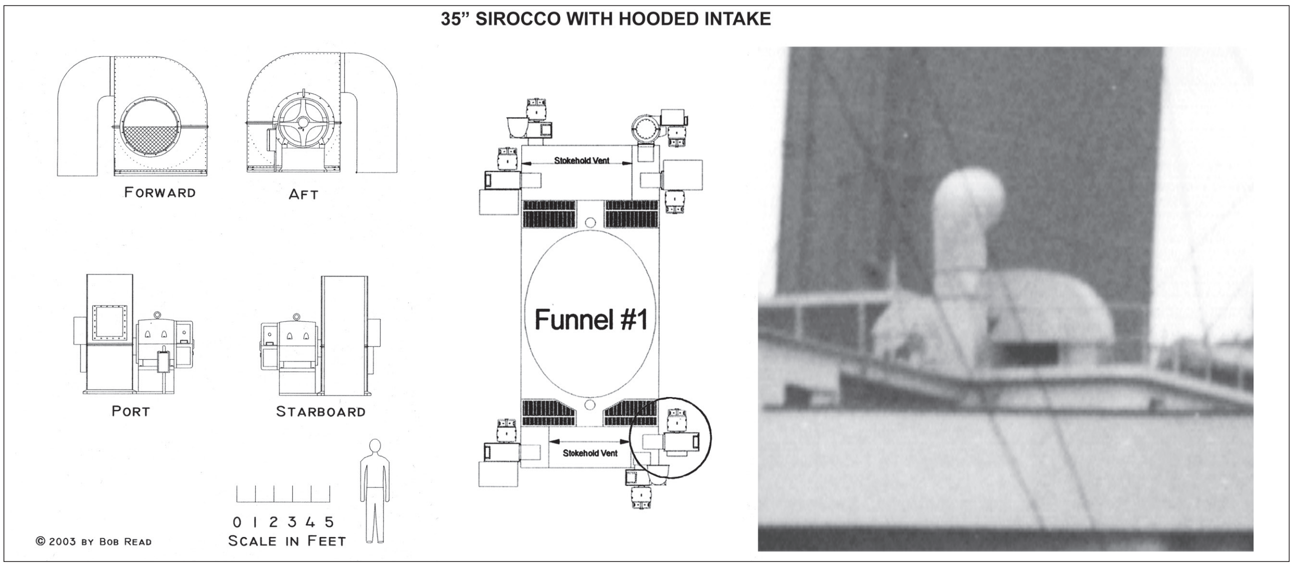

35" SIROCCO WITH HOODED INTAKE
Forward
Aft
Port
Starboard
Stokehold Vent
Funnel #1
Stokehold Vent
0 1 2 3 4 5
Scale in Feet
© 2003 by Bob Read

Fig. 19-42 **Hooded Duct Fitted to Sirocco Fan** – The duct configuration fitted to this Sirocco fan was unique on *Titanic*. The intake opening is half shrouded with a hood. Its design deceived artists and model makers for years until it was finally figured out and reported to the *Titanic* community by the author and Peter Davies-Garner. Contrary to how it appears in this image of *Titanic*, the hooded fan housing was not connected to the cowl ventilator right in front of it. *(Illustrations by Bob Read; image from authors' collection)*

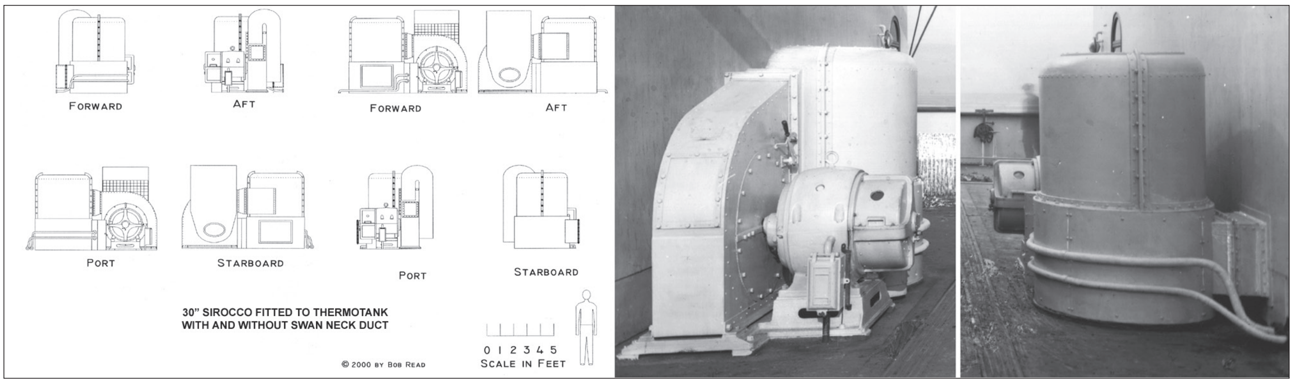

Forward
Aft
Forward
Aft
Port
Starboard
Port
Starboard
30" SIROCCO FITTED TO THERMOTANK
WITH AND WITHOUT SWAN NECK DUCT
0 1 2 3 4 5
Scale in Feet
© 2000 by Bob Read

Fig. 19-43 **Thermotanks** – Illustrations of two designs of thermotank. These were self-contained air heaters used on the *Olympic*-class ships. One version is shown with a swan-neck ventilator head, and the other with an unassisted opening covered with mesh screening. The photographs seen here are of the same thermotank from two angles, this thermotank being located between the No.3 Funnel casing and the reciprocating engine casing on *Olympic*. *(Illustrations by Bob Read/images from H&W in authors' collection)*

Ventilation of Galleys, engine spaces and other areas

As previously noted, the three forward funnels provided the necessary exhaust for the 159 boiler furnaces, but the No.4 Funnel exhausted both air and the byproducts of combustion from the Galleys, the First Class Smoke Room fireplace, the Turbine Engine Room and other areas.

The flue for the Crew's Galley located on C Deck (beneath the Forecastle Deck) rose along the port side of the foremast. The head of this pipe was fitted with a special cowl which rotated against the wind by means of a wind vane mounted on top of the cowl head. The wind vane ensured that the cowl head would always face away from the wind. As with the large cowl vents previously discussed, this helped maintain an updraft within the flue to ensure maximum ventilation and helped minimize the possibility of backdrafts even if the direction of the wind shifted rapidly.

HEATING

Ships of the British Empire carried passengers and cargo to all parts of the world and consequently experienced a great variety of weather conditions. Not only was the ship owner responsible for delivering perishable cargo in good condition, but also had to convey the passengers in comfort to encourage their booking future crossings with the same line. This necessitated the provision of good food, efficient service and well-furnished accommodations that were adequately ventilated and heated.

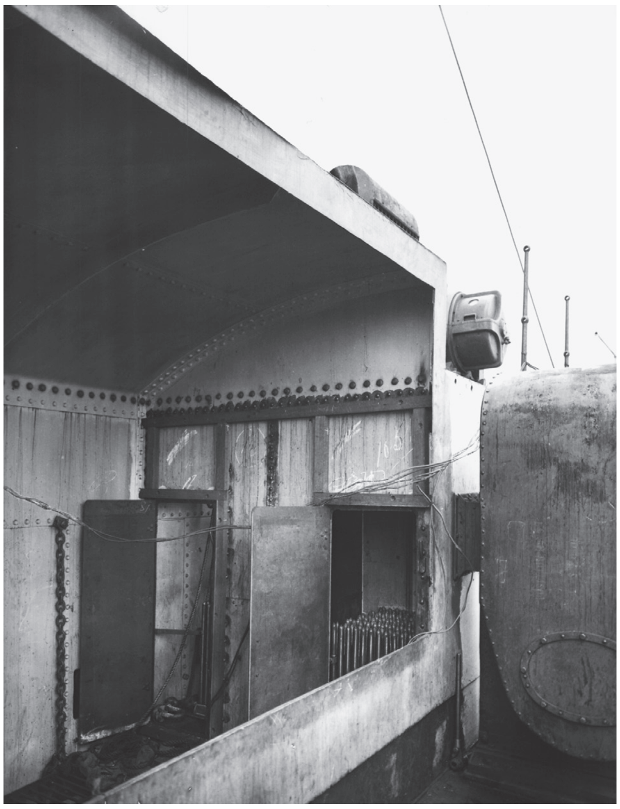


Fig. 19-44 **Stokehold Ventilator** – A view inside the stokehold ventilator aft of *Olympic*'s No.2 Funnel. Harland & Wolff referred to these as 'whaleback' ventilators. Located at the port and starboard ends of the casings were bundles of steam tubes within separate trunks; air forced into these trunks by Sirocco fans became heated in passing over the steam tubes. *(H&W/Authors' collection)*

When a ship passed quickly from a warm climate to a zone of cooler temperatures or transitioned from heat of the day to the cold of night, the vessel and her contents behaved much like a heated object removed from a furnace to the cool air outside. That is, the ship would begin to lose heat to the surrounding air. As this continued, the air inside the vessel would lose heat to the ship, and this process would continue until the interior eventually reached the same temperature as the surrounding atmosphere. In determining the heating requirements of a vessel such as *Titanic*, the builder's Heating Engineer estimated the rate – in heat units per hour – at which the loss through the sides and decks of the ship took place and then installed heating equipment of sufficient capacity to counterbalance this under the most severe conditions that the ship was likely to meet on her particular service route. By no means were these haphazard calculations; they were quite precise and involved set figures and formulas.

Allowance was first made for heat lost through leakage or carried away by the ventilating air. The unheated atmospheric air, which was blown into the compartments by fans and escaped through the exhaust ventilators, changed the air in these spaces a certain number of times per hour; as each air exchange would otherwise result in a loss of heat, this fresh air had to be heated if the interior temperature was to be maintained. On the opposite side of the equation, there were certain gains in heat to be deducted from the heating requirements. These included the heat from electric lights (approximately 340 BTU per hour per 100 Watts), a warm bulkhead or deck due to proximity of machinery, and body heat of the passengers and crew (about 400 BTU per person per hour at rest). Men working, such as waiters in a dining saloon, could produce considerably more heat (700 BTU per man per hour). Certain areas of the ship required less heat: staterooms over the boiler spaces needed very little heating, as the boilers below warmed the deck on which the staterooms were built. In fact, a warm deck was insulated with cork slabs to prevent the accommodation becoming overheated in warm weather as this source of warmth could not be cut off when desired in the manner that a system of warm air ventilators could be controlled.

Combined heating and ventilation was adopted aboard the *Olympic*-class liners in that the ventilating air was heated before it entered the passenger or crew

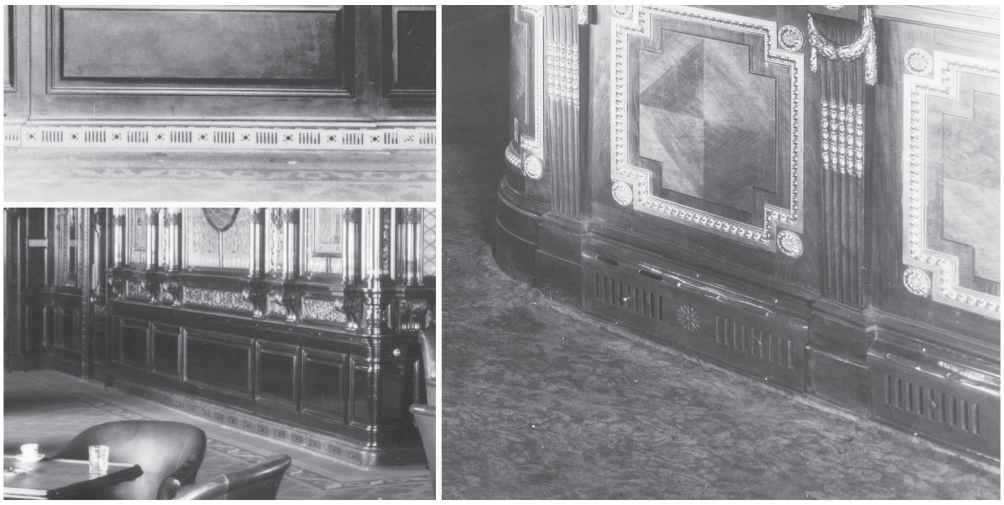


Fig. 19-45 **Pierced Grilles** – Pierced grilles along the deck level aboard *Olympic*. At left are two images from the First Class Smoking Room. At right is an image from the *à la carte* Restaurant buffet. *(Daniel Klistorner collection)*

accommodations. For First Class staterooms, the outside air was forced by fans over bundles of steam tubes in the boiler casings and then distributed to the various compartments by ducts. The steam-tube bundles were divided into two or three sections so that the amount of heating surface could be varied to suit the temperature of the outside air.

The objection to this form of heating was its inability to regulate the amount of ventilation within a room independently of the amount of heat furnished. Usually, a person desiring an increased amount of fresh air was unable to obtain it without the temperature of the room rising to an uncomfortable degree. This was overcome by a combination of direct and indirect heating, the incoming cool or cold air merely being tempered by the ventilation system heaters to maintain a temperature of about 65°F. This is what was described as the 'warm air' on the Plenum method. Supplementary heat as required was provided in the First Class staterooms by electric heaters, or radiators, which were under the direct control of the room's occupant. The warm air heat was generally limited to those compartments contingent with a boiler casing; these compartments were comprised almost entirely of First Class accommodations.

The areas contingent with a boiler casing within the public rooms had brass footboard grilles, accompanied by rectangular trunks generally 5in x 20in in cross-section. These were supplied by the warm-air delivery fans through the forward and after ends of the casings. Though period reference materials do not mention radiation pipe heating, there is ample evidence to suggest that some of the pierced brass covers actually encased lengths of steam piping. In his appraisal of *Olympic*, naval architect Leonard Peskett made specific reference to lengths of steam pipes on the casings at certain deck levels. Heating of this type is mentioned in *Olympic*'s 1935 auction book for companionways and public rooms. However, articles as late as 1914 on the *Britannic* mention only steam tubes and coils. This, however, would not preclude the use of common standing radiators in such places as the Tank Rooms on the Boat Deck.

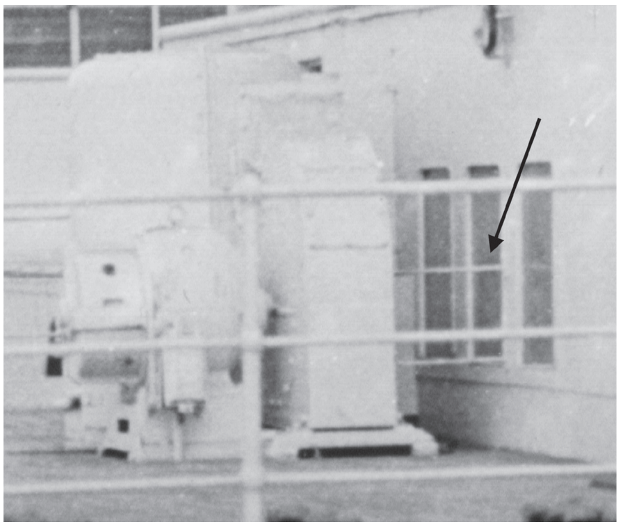


Fig. 19-46 **Thermotank with Guard Fence** – A guard fence protecting the intake opening of one of *Titanic*'s thermotanks on the raised roof over the First Class Smoke Room. These guard fences were not limited to thermotanks; they could be found by any of the Siroccos with unmodified intake openings that were located within the passenger promenade areas.

Live steam pipes of suitable size, properly encased and lagged, were also led to the pantries for heating water. These pipes were installed as directly as possible, and were independent of the bulkhead pipes. Heated water was stored in tanks with suitable drains provided as needed.

Hot air, as opposed to the warm air provided through the previously-described system, was provided through devices called 'thermotanks'. The word 'thermotank', as used in reference to the *Olympic*-class liners, only indicates a type of system, as the Thermotank Company which supplied systems to ships such as the *Lusitania* and *Mauretania*[11] had nothing to do with the installation on the *Olympic*-class ships – Harland & Wolff simply imitated their product. Thermotank devices heated the areas of the ship not covered by the warm air systems. These include, but were not limited to, those areas at the extreme ends of the ship and those places not readily accessible by the main air trunks contingent with the boiler casings, as well as all of the Second and Third Class accommodations and crew accommodations on E and F Decks.[12]

The principal characteristic of the Thermotank system was the same as for warm air, in that it was a combined heating and ventilation system. The air was heated before it was sent along the trunkways to the compartments, with the advantage that the incoming air did not cause cold drafts which, in cold climates, was the principal objection to ordinary mechanical ventilation. The 'thermotank' itself was a coil or bundle of steam tubes enclosed in a tank, through which the air was passed before entering the supply duct. Steam was supplied to the thermotank tubes from the boilers via a reduced-pressure supply line. The thermotank units were self-contained, and had the appearance of an upside-down drum attached to a Sirocco fan. They were positioned on deck out of the way of passengers when possible and, if the location required it, a special fence was installed in the area of the fan intake opening.

Electric radiators

Electric radiators were provided in all First Class staterooms, in the Officers' Quarters and in the foyers and entrance halls surrounding the First Class staircases

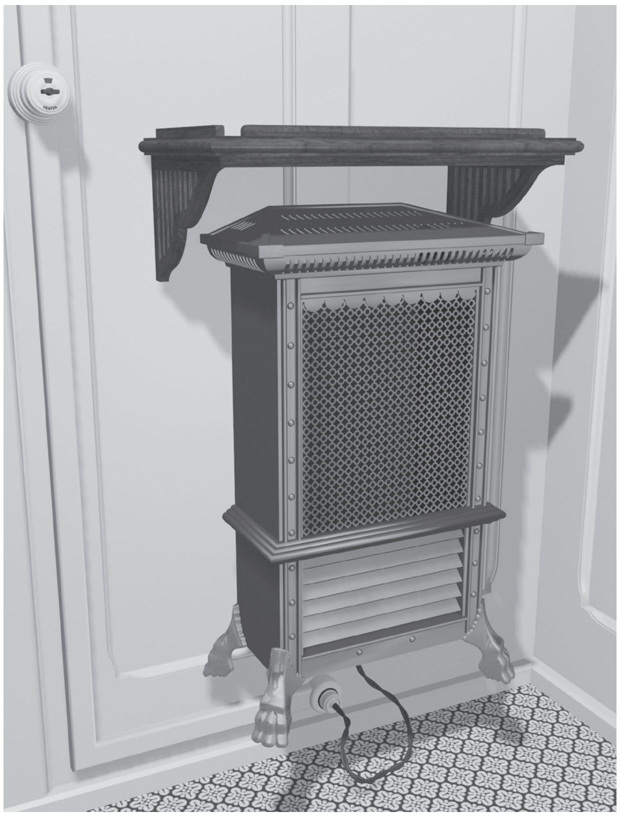


Fig. 19-47 **Stateroom Heater** – Artist's impression of one of *Titanic*'s stateroom heaters. Note the wooden shelf fitted above. *(Illustration by Michael McMillan)*

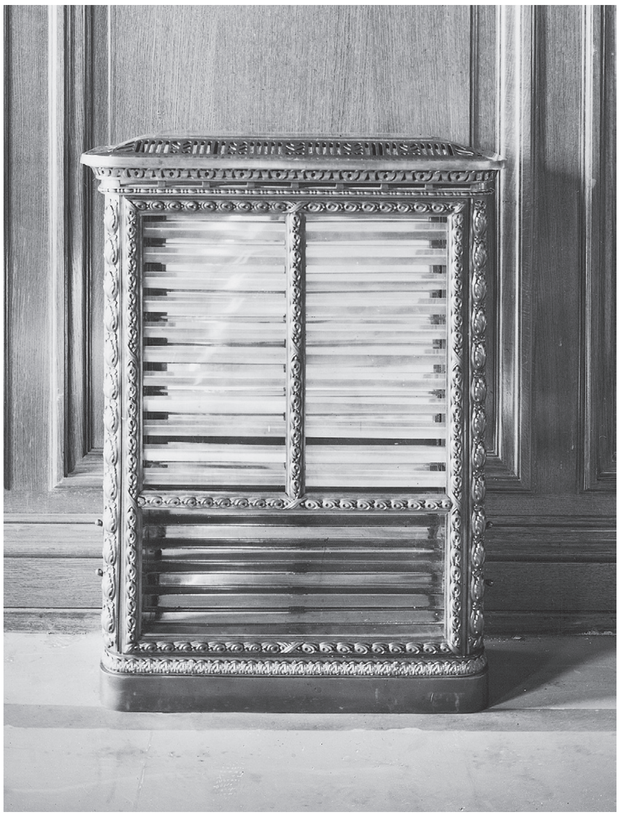
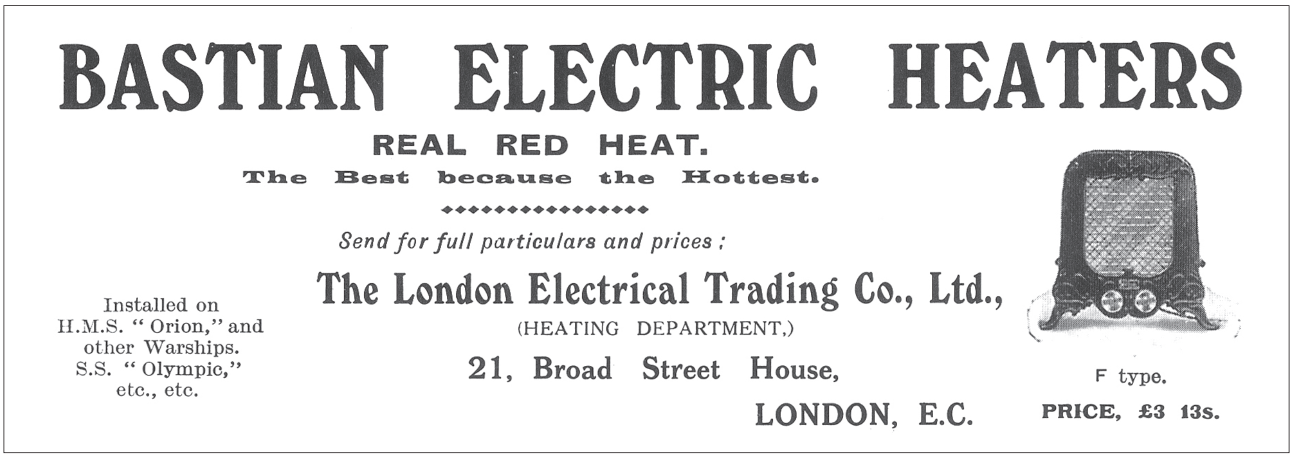


Fig. 19-48 **Bastian Heater –** A Perry & Company 'Real Bronze Radiator' with prismatic bars as seen in a First Class companionway on *Olympic*. *(Daniel Klistorner collection)*



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etc., etc.

F type.

PRICE, £3 13s.

Fig. 19-49 **Bastian Heater Advertisement**. *(*The Shipbuilder*/Authors' collection)*

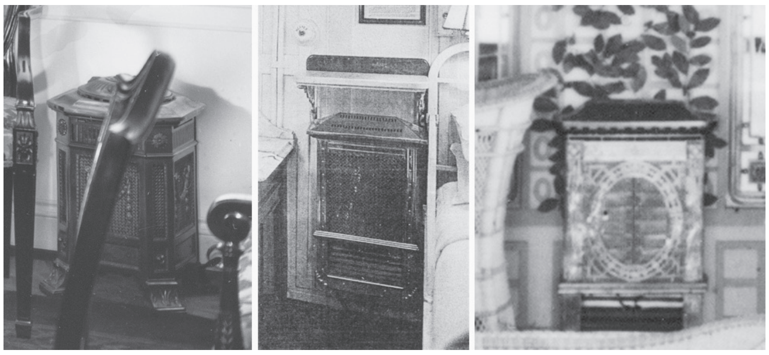


Fig. 19-50 **Prometheus Heaters –** At left, an example of a 1000-watt heater as seen in a First Class sitting room from one of the Parlor Suites. At center, a larger 2000-watt heater from a standard First Class stateroom, and at right a 2000-watt unit as fitted in the A Deck Verandah cafés. *(Daniel Klistorner collection)*

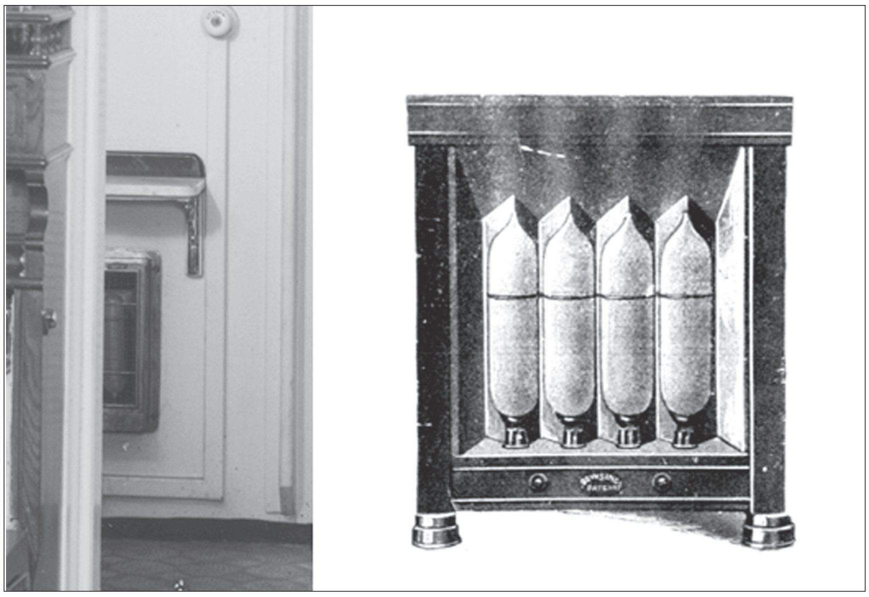
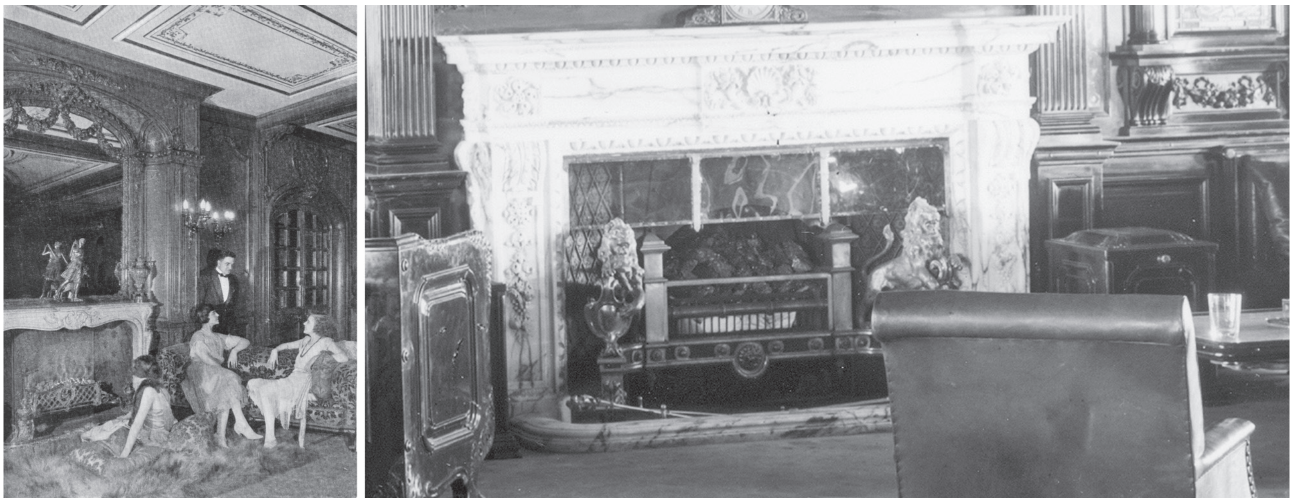


Fig. 19-51 **Dowsing Heater** – At left, just visible through a bathroom door from a D Deck stateroom on *Olympic*, the edge of a Dowsing heater can be seen. At right is an illustration from a period magazine advertising a Dowsing heater similar to those used on the *Olympic*-class liners. *(Daniel Klistorner collection)*



Above Fig. 19-52 **Fireplaces** – Both of these images are from *Olympic*. At left, a group of ladies seated in front of the *faux* fireplace in the First Class Lounge. At right, the only working fireplace on the ship – the one in the First Class Smoke Room. The box to the right of the fireplace with the knob on its face was one of two coal boxes. *(Both images from Daniel Klistorner collection)*

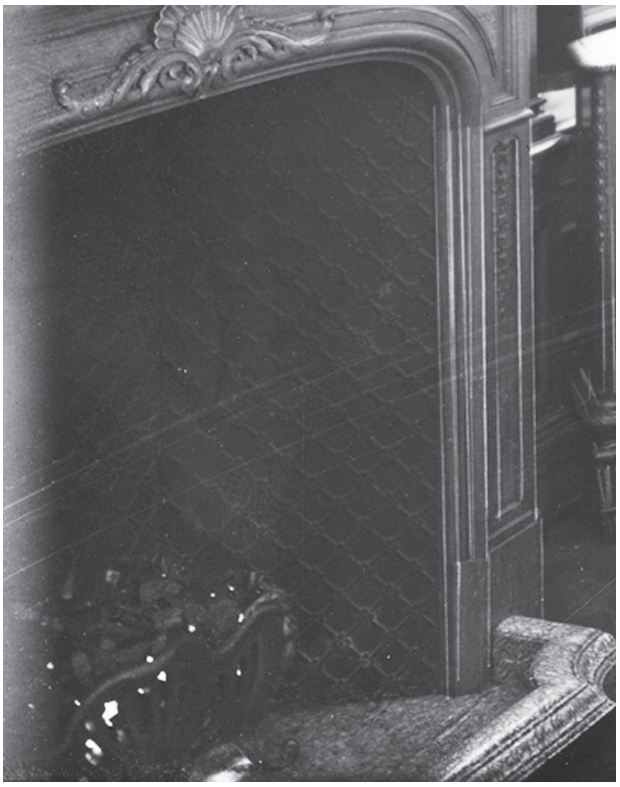


Fig. 19-53 **Electric Fireplace** – A 'lit' fireplace in the sitting room of a C Deck Parlor Suite on *Olympic*. Unlike the one in the First Class Smoke Room, these had artificial fires; the electric heating elements are aglow behind the decorative 'coal' facade. *(Daniel Klistorner collection)*

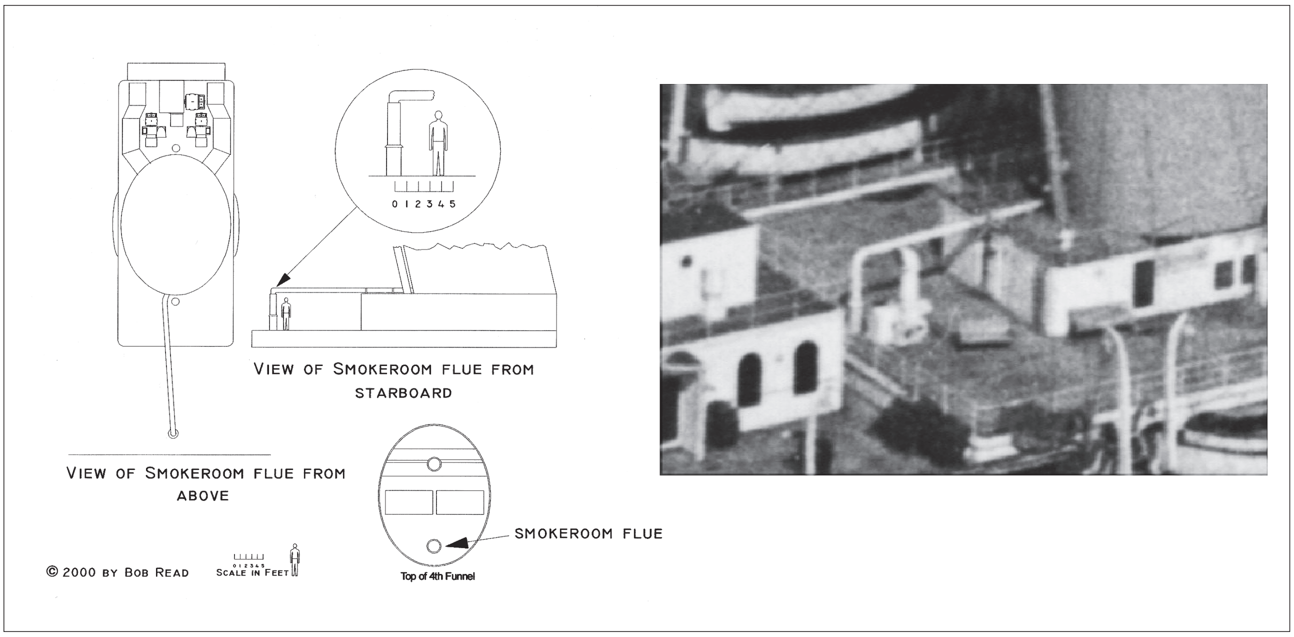


Fig. 19-54 **Smoke Room Flue** – An illustration and photograph of *Olympic* showing the First Class Smoke Room fireplace flue and the point at which it entered the base of the No.4 Funnel. *Olympic* was not provided with this arrangement as fitted out in 1911, but would be modified shortly thereafter. *Titanic*'s fireplace flue was directed into an internal flue within the No.4 Funnel from the beginning, Harland & Wolff having learned from *Olympic*. *Olympic*'s flue was originally led to a level just above the First Class Smoke Room's raised roof, and apparently caused the Second Class promenade to be frequently filled with acrid coal smoke and soot. The original design was changed in a short period of time. *(Illustrations by Bob Read/image from authors' collection)*

and in other areas where supplemental heat was needed. They were also placed in large public rooms to supplement the main heating units or to heat the whole compartment if necessary. The heaters were ideal for stateroom use – they were compact and neat in appearance and easily turned off and on, allowing the occupant to regulate room temperature to any desired level. They were connected by simple wiring which was more flexible and more easily concealed than steam piping.

Electric radiators used within the passenger staterooms, Officers' Quarters and First Class Verandah cafés were manufactured by the British Prometheus Company. These were enclosed in brass cases and raised slightly off the floor to allow air circulation up through the interior. Holes were cut through the enclosures to allow the egress of hot air. The Prometheus heaters were of the non-luminous type and operated with the use of heating elements known as convectors, which could be adjusted for temperature as needed by the passenger. The convection type of heat was mandatory, as direct radiation was dangerous in staterooms and other confined areas due to the risk of fire.

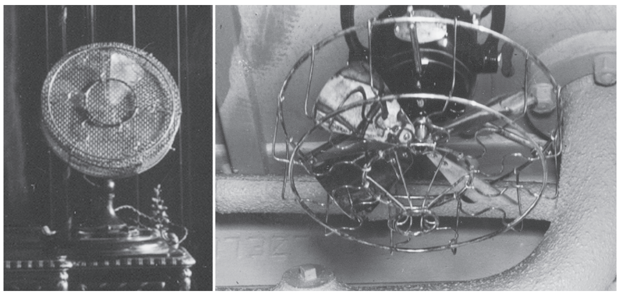


Fig. 19-55 **Rotary Fans** – In these details from *Olympic* photographs, two fans are pictured – one a table version and the other of the type mounted to the deckhead in First Class staterooms. *(Daniel Klistorner collection)*

The radiators used in the entrance halls were termed 'real bronze radiators' and were supplied by Perry & Co. Inside were Bastian heating elements from the Bastian Electric Heating Syndicate Ltd, London. Fitted in front of the radiators were cut-glass prismatic bars of a design that projected the heat in a wider array. The Bastian radiators were approximately 2ft wide and were arranged around the perimeter of the entrance halls.

All of the First Class bathrooms were provided with electric heaters manufactured by the Dowsing Company. These radiators provided heat by means of three custom-made, carbon-filament incandescent lamps, each approximately 9in long with a single horseshoe-shaped filament. These incandescent lamps were termed 'glow-lamps'[13] and were maintained at a red heat; although they were termed 'lamps', they provided heat rather than light. The lamps were held in an ornamental enclosure with a reflector placed at the back to throw the heat from the lamps into the room. Switches were connected to operate any number of lamps within the fixture; heat was regulated by the number of lamps which were lit.

Specifications of electric heaters fitted aboard *Titanic* were as follows:

81	2,000-watt Prometheus heaters for First Class staterooms
284	1,000-watt Prometheus heaters for First Class staterooms
3	2,000-watt Prometheus heaters for ship's officers, etc.
14	1,000-watt Prometheus heaters for ship's officers, etc.
14	2,000-watt Prometheus heaters for First Class Verandah cafés
24	3,500-watt Bastian heaters for First Class entrances
8	6,000-watt Bastian heaters for First Class entrances
95	750-watt Dowsing heaters for First Class bathrooms
1	750-watt Dowsing heater for Captain's bathroom

Fireplaces

The fireplaces in the elegant First Class staterooms and most of the First Class public rooms were given the appearance of being functional. Ceramic 'coal' was actually placed into dog grates within the fireplace openings, but the heat was delivered from an electric heater. The staterooms fitted with fireplaces were generally provided with 18in wrought-iron basket electric radiators with imitation coal fires. The area around the fireplaces was bordered by extravagant fireplace surrounds and ornamental curbs at deck level.

The only operational fireplace in the ship was in the First Class Smoke Room. This fireplace was fueled by coal and came equipped with all of the tools necessary for using it. The insulated metal chimney exited the roof of the Smoke Room where, after rising to the height of the deckhouse roofs, it turned 90° and continued forward where it entered the after side of the No.4 Funnel to port of center just above its base. It should be noted that the chimney flue was taken internally all the way to the top of the funnel; it did not simply end where it entered the side plating of the funnel. As with the galley flues vented into this funnel, care was taken that waste gases could not find their way back into the ship.

Portable and bulkhead-mounted electric fans

To assist in temperature control and promote air circulation, *Titanic* was fitted with over 400 electric rotary fans, both table and beam type. These not only graced First Class staterooms, but also public rooms such as the Dining Saloon, *à la carte* Restaurant, First Class Reception Room, and the Maids' and Valets' Saloon. The fans were 12in in diameter across the blades and connected to an outlet in the bulkhead by a colored, flexible cord. Some were the swiveling type and could be used on brackets on the bulkhead. These fans had regulating switches enclosed in their bases. The finish varied depending on the surroundings: some were of electroplated metalwork with white-and-gold bodies, others were plain brass with black bodies.

Overview of Ventilation and Heating in Passenger and Crew Compartments

In 1911, Cunard's Leonard Peskett wrote some unfavorable notes on *Olympic*'s ventilation system for the First Class areas. In his notes he stated that

> *The systems employed, and the power and trunking are such as would be approved by most ventilating experts. When one takes into consideration the enormous number of electric lights, the confined heat in machinery spaces and the want of means of circulation, it is not surprising that a high temperature prevails in most of the cabins. The example: take all of the best-class of rooms on 'C' deck. The en-suite rooms are located next to the skin of the ship, and inside rooms are around the funnel casings and close sealed. The outside rooms are ventilated by the ports, and the inside rooms by trunks and louvers. The fans supplying the trunks with air are in some cases so far away that the supply in some of the cabins is very feeble. There are no athwartship corridors with ports at the ends, or any other means provided to circulate the air, consequently the smell from the inside rooms in the morning after two of three persons have been sleeping in them is very objectionable.*

These problems were addressed on *Titanic* (and later, on *Olympic*) by fitting more cork insulation between the machinery casings and the cabins, adding electric fans, and beefing up the Sirocco installations. The specifications which follow were taken from Peskett's notes on *Olympic*, written following his eastbound crossing aboard her August 19–25, 1911. Additional notes have been taken from Harland & Wolff's Drawing Office specification book for *Olympic*, and her auction book. Mr Peskett's notes have been quoted in full, including his sometimes caustic and occasionally humorous personal observations:

> *The air from all lavatories, galleys and pantries are exhausted by powerful fans, the inlet of fresh air being by the entrances to the lavatories etc., and the ports only.*

All First, Second and Third Class Public rooms; also Second, Third Class and crew's quarters are heated and ventilated by the Thermotank system.[14]

First Class staterooms are ventilated and heated as follows: -

Fore End of A Deck
Outer rooms ventilated by windows; inner rooms ventilated by jalousies and flaps. Rooms heated by electric radiators.

Fore and aft alleyway heated by steam pipe running fore and aft on the machinery casing.

Alleyway ventilated by trunk in casing, and by port at the fore end.

Inner rooms on A deck are lighted by two fixed oval coaming lights.[15]

Cross corridors are lighted and ventilated by Utley's French windows.

Lounge and smoke-room corridors heated and ventilated by the Thermotank system.

B Deck
Rooms at forward end are all on the Bibby principle and ventilated by the ports. Alleyways are ventilated by trunks and the ports at forward end.

Forward section of 'B' deck rooms are heated by electric radiators, and alleyways heated by a steam pipe on machinery casing;

Special En-suite rooms on 'B' deck are ventilated by the windows. The framing forming the fore and aft corridor is close-sealed, with the exception of the jalousied panel on the lower part of the door. These rooms are 16ft from the curtain plate on 'A' deck, and get very little air through the ports. The inside rooms are ventilated by trunks, but the want of currents in the fore and aft passages makes these rooms very stuffy.

Fore and aft corridor abaft main stairway heated and ventilated by the Thermotank system.

C Deck
Forward rooms on the Bibby principle are ventilated by Utley's rectangular pivoted ports, and also by a 24in x 8in trunk fitted along the ship's side with the louvers into room on to the bed next the ship's side.

The suite rooms ventilated by ports, and heated by electric radiators. Inside rooms ventilated by louvers in air trunks, heated electrically.

Fore and aft corridors heated and ventilated by Thermotank system.

Nearly all the First Class cabins throughout have been fitted with fans.

D Deck.
Rooms forward of the saloon ventilated by ports and trunk under bed at side, heated by electric radiators.

E Deck.
In order to get circulation of air in the corridor to First Class rooms at the fore end of 'E' deck a door of wire netting has been fitted to get a current of air from the adjacent Third Class stairway. It occasionally obtained more foul language than fresh air.

[Authors' note: although Peskett doesn't indicate this, the rooms which follow were on the Boat Deck.]

Officers' quarters, Marconi rooms, etc. are heated by steam.
Captain's quarters are heated by electric radiators.

[Authors' note: the following is also Peskett's:]

Note. The word 'Thermotank' has been used above to describe a system only. The Thermotank Co. had nothing whatever to do with the installation, it being a poor imitation carried out by Harland & Wolff.

Compartments serviced with Sirocco air extraction fans
Officers' lavatory on Boat Deck; First Class Lounge; First Class Reading and Writing Room; First Class Smoke Room; First Class Verandahs; First Class à la carte Restaurant Galley on B Deck; First and Second Class Galley on D Deck; First Class Dining Saloon port and starboard on D Deck; First Class ladies' and men's lavatories and water closets on A, B, C, D and E Decks, and en suite bathrooms and water closets on B and C Decks; First Class Pantry on D Deck; First Class Pantry and Service Rooms on E Deck; Turkish Baths on F Deck; Second Class Smoke Room, Second Class Library, Second Class Dining Saloon and Second Class Pantry on D Deck; Second Class ladies' and men's lavatories on E and F Decks; Engineers' lavatories on F Deck; Second Class ladies' and Stewards' lavatories on E Deck; Linen Room and Pantry on E Deck; Maids' and Valets' Saloon on C Deck; Chief Engineer's lavatory on F Deck; Hospital Rooms on D Deck; Third Class Galley on F Deck; Third Class Dining Saloons having 30in x 9in 18 WG suction trunks along boiler casings connecting with the Fan Rooms for delivering air to stokeholds, Second and Third Class men's lavatories on D Deck; Infectious Hospital Rooms and crew lavatories on D, E, F and G Decks.

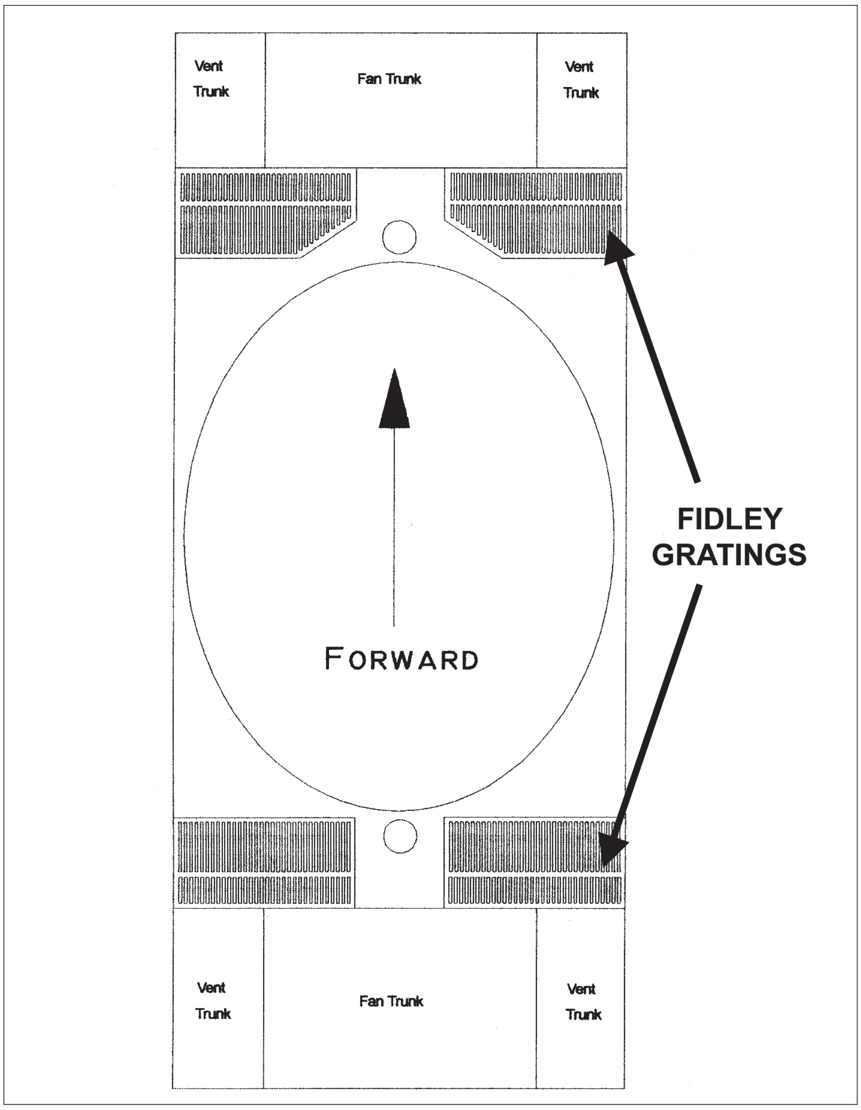


Fig. 19-56 **Fidley Diagram**.
(Illustration by Bob Read)

Compartments serviced with ventilation fans providing warm air
First Class Lounge, First Class Reading and Writing Room, First Class Smoke Room on A Deck; First Class à la carte Restaurant on B Deck; First Class corridors on A and B Decks; First Class accommodations on C, D and E Decks; First Class staterooms and corridors on C Deck; Hospital Rooms on D Deck; First Class Reception Room and Dining Saloon on D Deck; Squash Racquet Court on G Deck; Second Class accommodations on E and F Decks; Waiters' accommodations on E Deck.

Compartments serviced with ventilation fans providing hot air on the Thermotank system
Second Class Dining Saloon on D Deck; port-side Second Class accommodations on D, E, F and G Decks, starboard-side Second Class accommodations on D, E, F and G Decks; Second Class Library on C Deck, Turkish Baths on F Deck; crew accommodations on D, E, F, and G Decks forward; Post Office on G Deck; Third Class accommodations and Seamen's accommodations on E Deck; Third Class accommodations on D, E, F and G Decks; Stewardesses' accommodations on A and B Decks; Stewards' accommodations on E and F Decks; Soiled Linen and Drying Rooms on F Deck; Stewards' accommodations on F Deck; Electric Bath on F Deck, Engineers' Mess port and Second Class accommodations starboard on E Deck; Engineers' accommodations port and starboard on F Deck.

STOKEHOLD VENTILATION

The machinery and boiler spaces required large volumes of fresh air to carry away air heated by the machinery and boilers and to support the combustion in the furnaces. Assisting the downward current of fresh air were large Sirocco fans. These fans – the largest and most powerful on the ship – ensured thorough ventilation and ample air for the furnaces independently of wind and weather. Although this meant that the supply of air to the stokeholds[16] and furnaces was established to a certain extent by artificial means, the fact that the heat from the boiler rooms was vented through open fidley trunks precluded the possibility of any actual pressure to the air, and consequently the draft through the furnaces and the combustion was natural rather than forced. The expression 'natural draft' was therefore applicable, but 'induced draft' was more appropriate, and was the term generally used, the former being reserved for cases where there were no fans at all supplying air to the stokeholds.

Designing a funnel to provide the correct amount of natural draft involves a number of design factors. When coal is burned in a boiler furnace, the hot combustion produces gases termed 'flue gases'. Aboard ship, those gases need to be exhausted to the outside air through the ship's funnels. The flue gases inside the funnels are much hotter than the ambient (outside) air and therefore less dense. That causes the bottom of the vertical column of hot flue gas to have a lower pressure than the pressure at the bottom of a corresponding column of outside air. While hot flue gases will rise by themselves due to thermal buoyancy, the higher pressure outside the furnace is really the driving force that moves the required combustion air into the furnace and also moves the flue gas up and out of the funnel. That movement or flow of combustion air and flue gas is called 'natural draft'. On ships like *Titanic*, the air required for combustion had to first descend an average distance of 90ft from the stokehold ventilators to reach the furnaces situated along each of the stokeholds below. If it were not for the Sirocco fans, the volume of fresh air reaching the furnaces would have been insufficient for proper combustion – when all boilers in a particular boiler room were being fired, the combustion in the furnaces would have been sluggish or incomplete, and the stokeholds would have become unbearably hot. Fitting the large Sirocco fans to increase the airflow eliminated these problems.

Titanic was fitted with twelve Sirocco fans for this purpose, two for each boiler room. The fans were placed on the F Deck level and drew in air from ventilating trunks on the Boat Deck, located fore and aft of the first three funnels. The air from the fans was distributed to points immediately above the furnace openings in the boiler rooms. The speed of the fans was adjusted by controllers located in the Fan Rooms. The controllers could be worked locally within the fan rooms or from the stokeholds by rods supported on ball thrusts. More information on these fans and their operation may be found in the chapter dealing with the propelling machinery.

Specifications for stokehold fans

Two 40in-diameter Sirocco fans in Fan Room aft of No.1 boiler casing on F Deck.

Delivered air to the Boiler Room No.1. Motor 15BHP. Controllers near fans in Fan Room.

Two 55in-diameter Sirocco fans in Fan Room forward of No.2 boiler casing on F Deck.

Delivered fresh air to Boiler Room No.2. Motor 30BHP. Controllers near fans in Fan Room.

Two 55in-diameter Sirocco fans in Fan Room aft of No.3 boiler casing on F Deck.

Delivered fresh air to Boiler Room No.3. Motor 30BHP. Controllers near fans in Fan Room.

Two 55in-diameter Sirocco fans in Fan Room forward of No.4 boiler casing on F Deck.

Delivered fresh air to Boiler Room No.4. Motor 30BHP. Controllers near fans in Fan Room.

Two 55in-diameter Sirocco fans in Fan Room aft of No.5 boiler casing on F Deck.

Delivered fresh air to Boiler Room No.5. Motor 30BHP. Controllers near fans in Fan Room.

Two 50in-diameter Sirocco fans in Fan Room forward of No.6 boiler casing on F Deck.

Delivered fresh air to Boiler Room No.6. Motor 25BHP. Controllers near fans in Fan Room.

Ventilation of the stokeholds was also required to carry away the heat that would build up as a consequence of the furnaces, boilers and steam piping. Temperatures in the stokeholds could routinely reach 110°F under normal circumstances, and without a means to vent this heat the stokeholds would have become unbearable for even the hardiest stoker. On the casings for the first three funnels, and situated directly against the forward and after edges of each funnel, sat elongated areas of gratings. These were the foot grates over the fidley trunks. The fidley trunks were essentially multi-purpose ventilation shafts; they ran down to the top of the stokehold, paralleling the stokehold ventilation trunks. Whereas the ventilation trunks conveyed air into the stokehold, the fidley trunks conveyed hot air up and out of the ship. To promote the flow of air upwards through the fidley trunks, the speed of the stokehold fans was adjusted to provide a greater volume of air than the furnaces required. The use of Sirocco fans for this purpose also permitted the adoption of smaller fidley openings and trunks than if natural ventilation alone were employed.

ENGINE ROOM VENTILATION

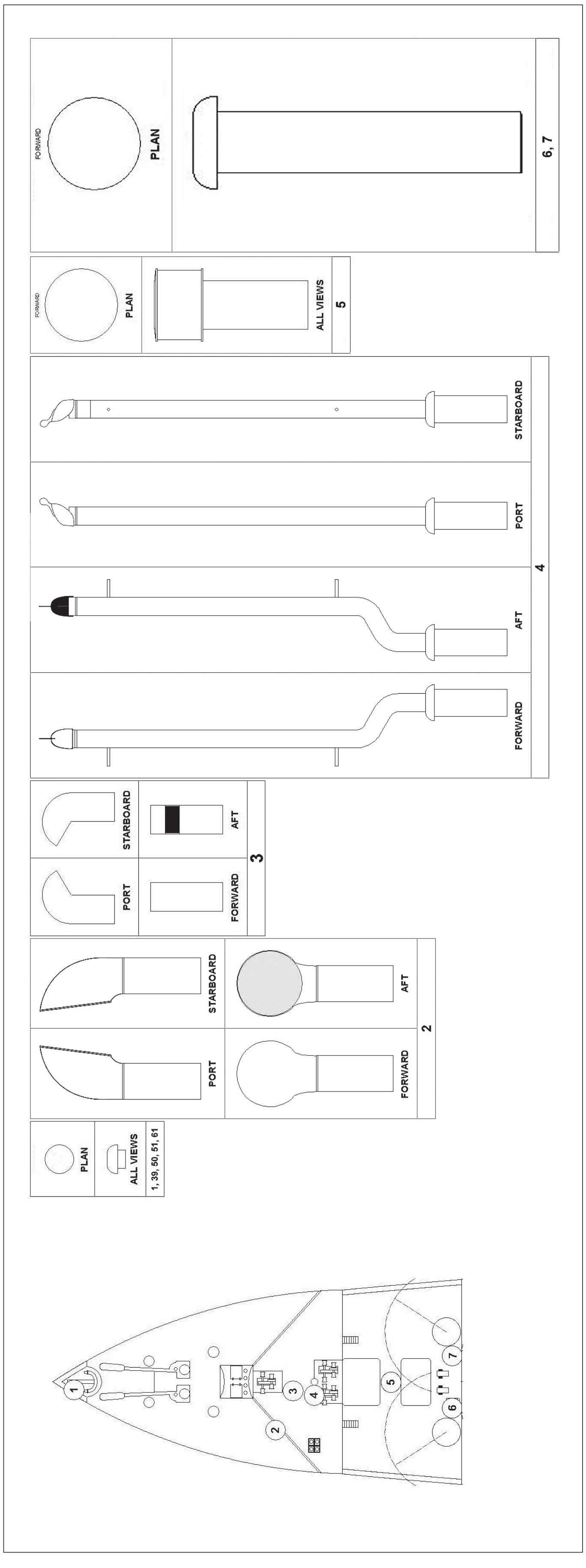
Adequate ventilation of the compartments occupied by the main and auxiliary machinery was not only essential to prevent deterioration of the engines, dynamos, motors and hull structure of the vessel, but also to maintain the health and comfort of those running the machinery. The machinery installation in vessels of the time had become so large and complex that it could only be properly handled under the best conditions. At the various control positions, switchboards and other stations where the men had to make observations or operate machinery, insufficient light or fresh air was bound to result in fatigue and a loss of efficiency and could culminate in the breakdown of some important section of the plant.

Titanic's enormous reciprocating engines required more headroom than most machinery plants of the time. Consequently, the compartment which housed them was cavernous in size. To ventilate this large space, the compartment was extended upward in the form of a hatch trunk terminating in a skylight on the Boat Deck. Fresh air was conveyed from above by the inlet trunks to the Starting Platform located at the lowest level between the two engines.

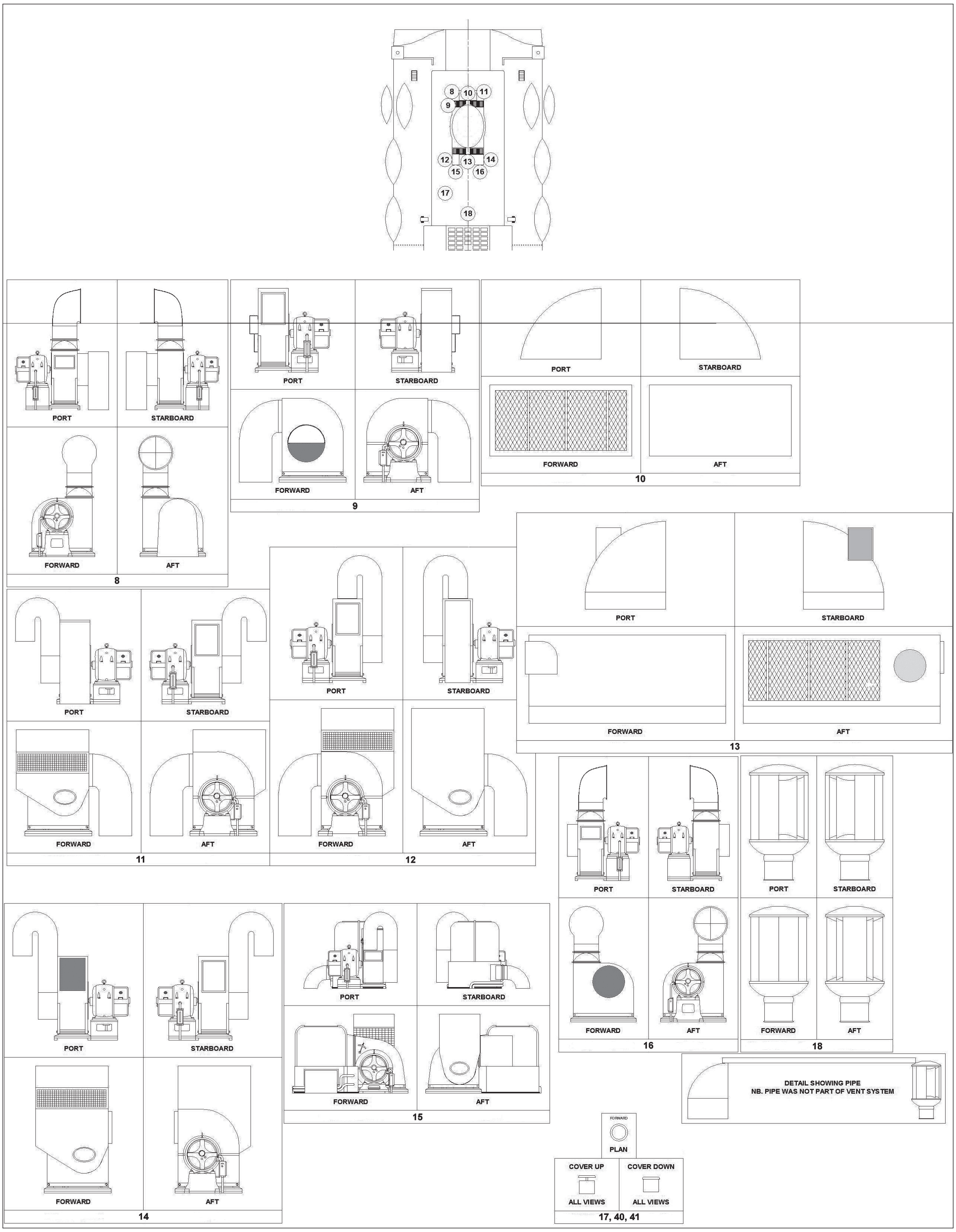
The space occupied by the turbine engine fell into a different ventilation category. Owing to the low height of the machinery and the large amount of floor space occupied, the lower decks could be carried continuously over the Turbine Engine Room, substantially reducing the volume of the compartment. As a consequence, the ventilation trunks employed were of much smaller proportions than those required in the case of the Reciprocating Engine Room.

Providing adequate ventilation to such large spaces necessitated running supply and exhaust trunks to all parts of the engine spaces. The fresh air was delivered as low down in the compartment as possible and special attention was given to recesses, pockets, and pipe tunnels. The shaft tunnels also required proper ventilation; this was combined with the escape trunk at the after end of the ship.[17]

A light-and-air shaft was fitted over the Reciprocating Engine Room on the Boat Deck. A similar shaft was fitted over the Turbine Engine Room but was surmounted by the No.4 Funnel. The ventilation of the engine rooms was further assisted by six



Figs 19-57 to 63 **Locations of Ventilators on *Titanic*** – This series of plan views and elevations show the configurations and locations of all of *Titanic*'s ventilators visible on the weather decks. *(Illustrations by David Cotgreave)*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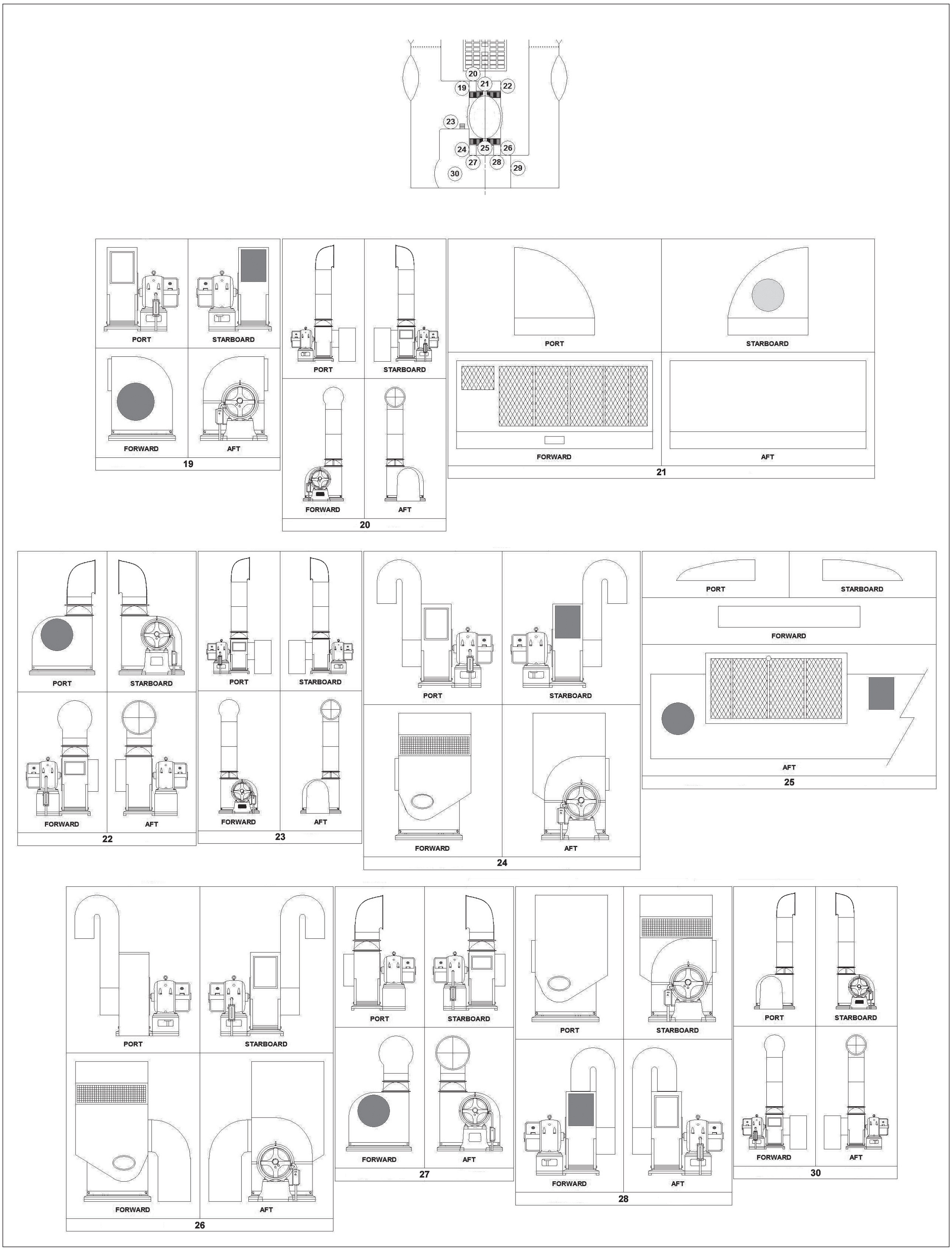
Sirocco fans, of which four were placed in the Reciprocating Engine Room and two in the turbine engine casing. Of the four fans in the Reciprocating Engine Room, two were placed in the skylight shaft and supplied air to the vicinity of the starting platform through a series of trunks, while the other two were situated on the port and starboard sides respectively and ventilated the wings of the compartment. The controllers for each were located in the Reciprocating Engine Room.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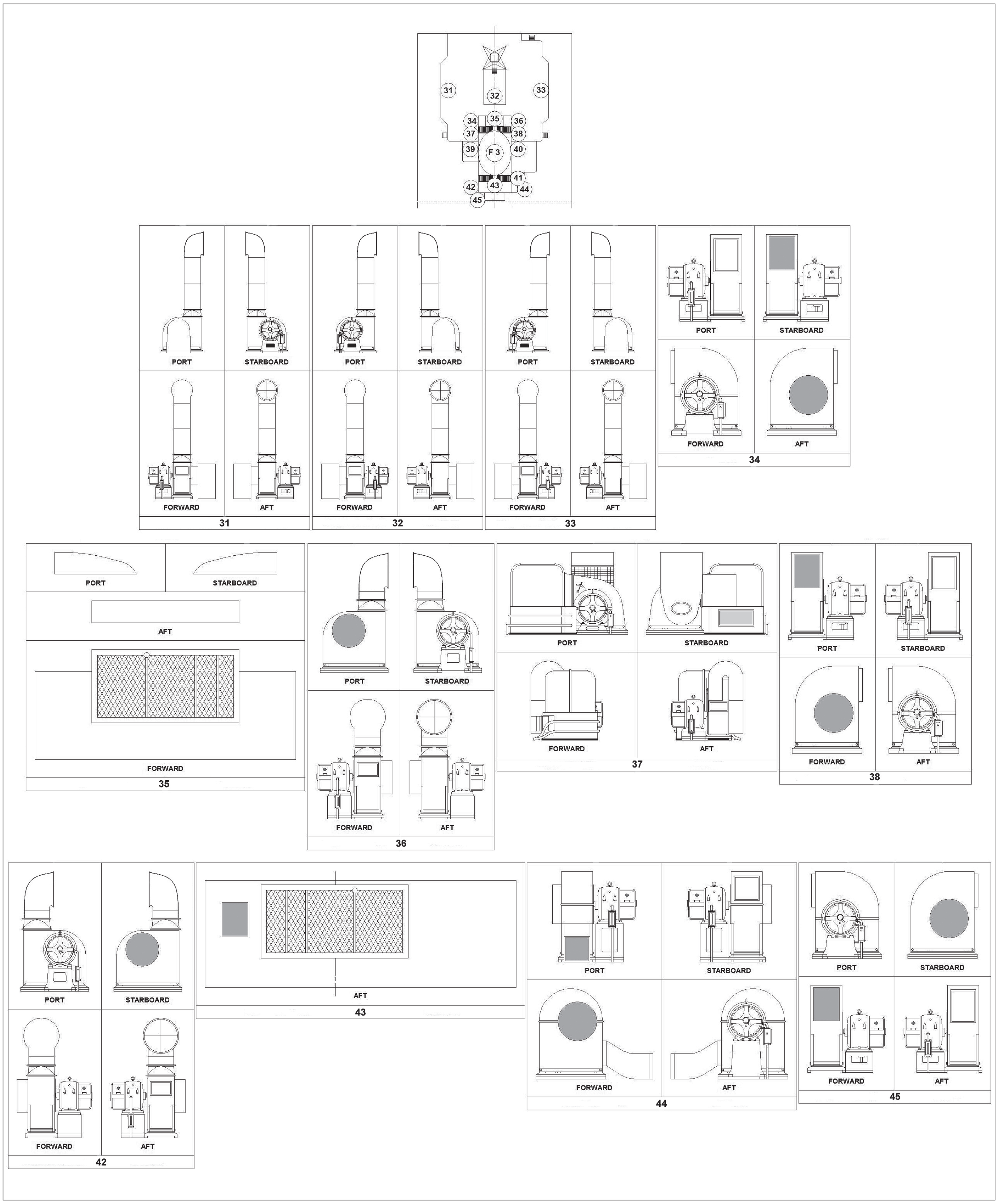
Specifications for ventilation of the Reciprocating Engine Room:

Two 35in-diameter Sirocco fans with 10BHP motors; located at B Deck level port and starboard in after end of reciprocating engine casing, delivering air above Starting Platform.

Two 30in-diameter Sirocco fans with 7½BHP motors; located port and starboard on G Deck abaft the Engineers'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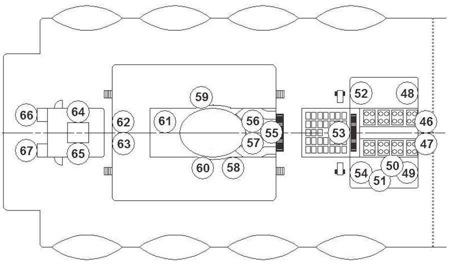
Store Rooms; delivering air to port and starboard Reciprocating Engine Room wings, respectively.

A supplemental Sirocco fan of 40in diameter driven by a 15BHP motor was located in the turbine engine casing and drew air from the Reciprocating Engine Room.

Ventilation of the Turbine Engine Room was provided by a Sirocco fan of 30in diameter driven by a 7½BHP motor; this fan unit was located within the Fan Room abaft the Turbine Engine casing and beneath the No.4 Funnel.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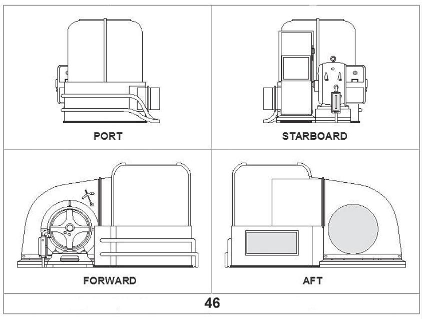
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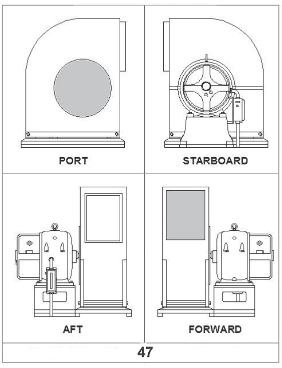
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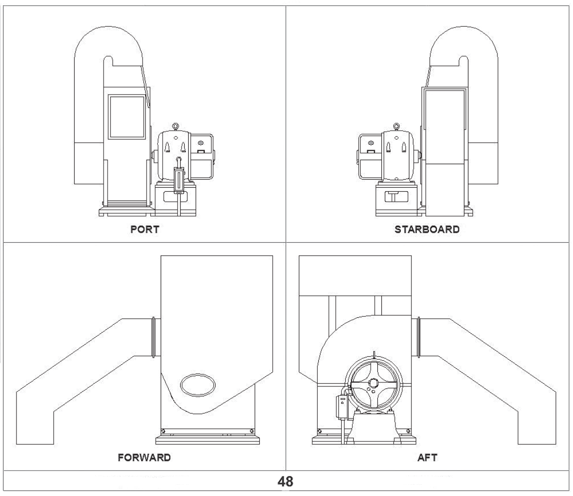
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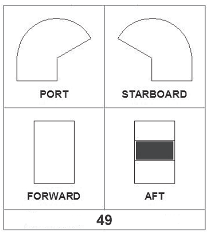
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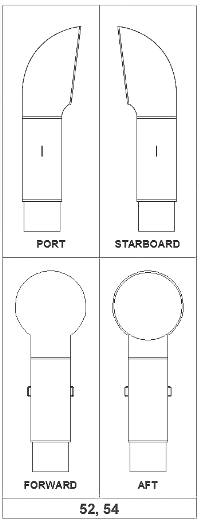
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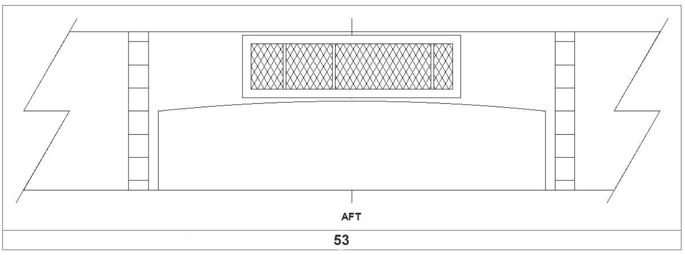

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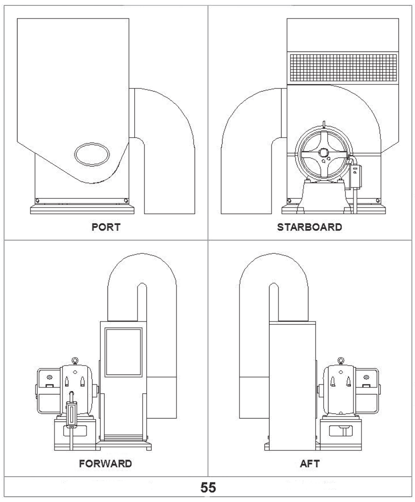
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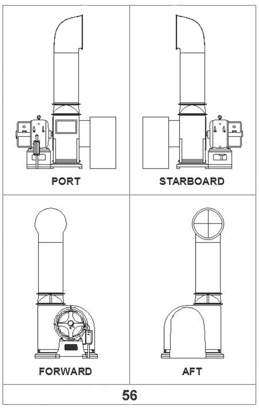
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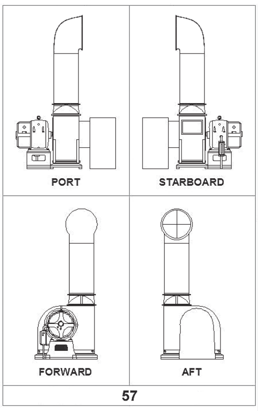
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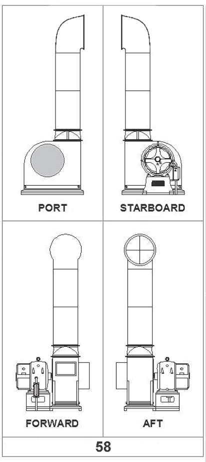
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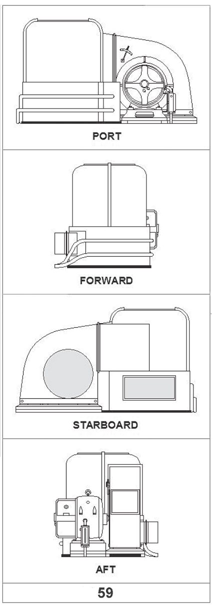
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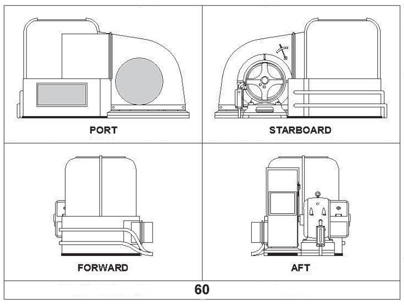
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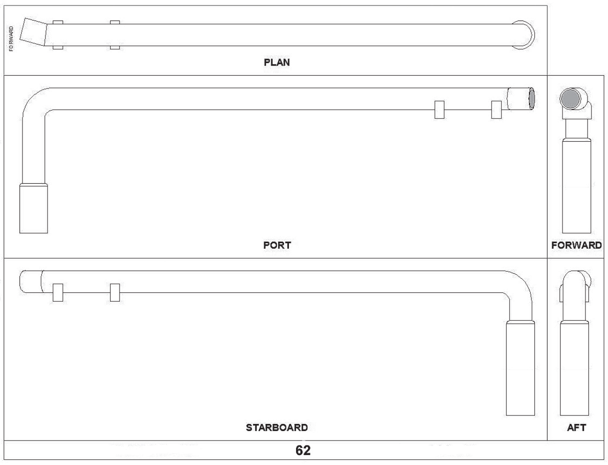
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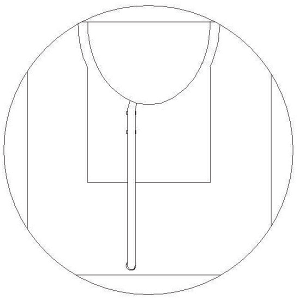

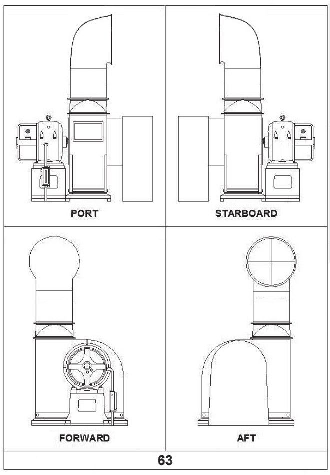
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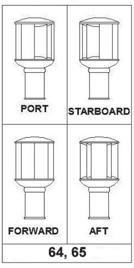
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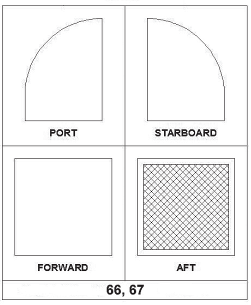
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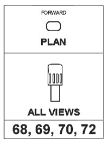
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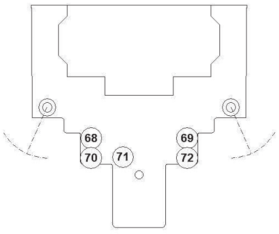
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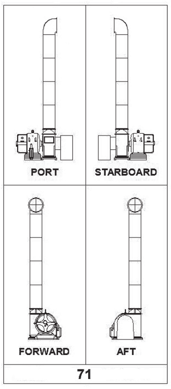
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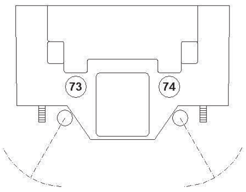

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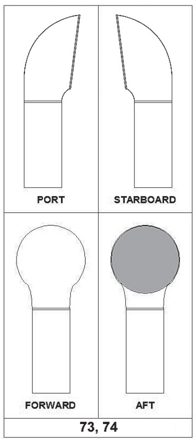
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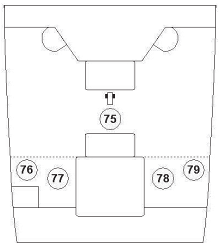
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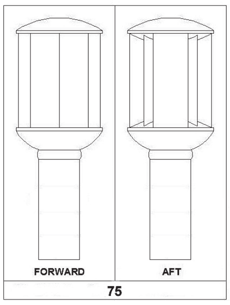
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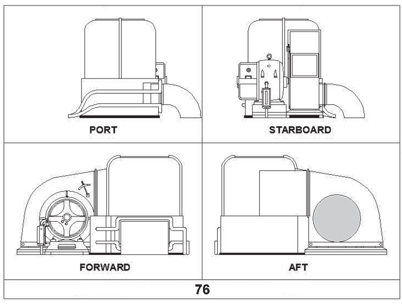
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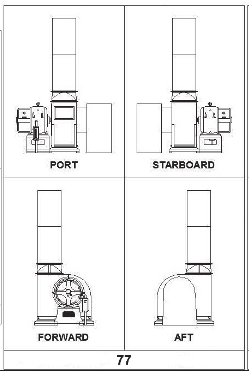
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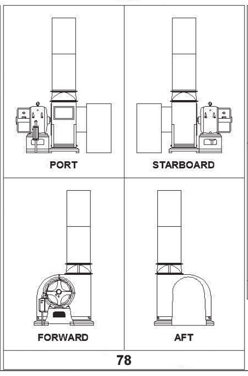
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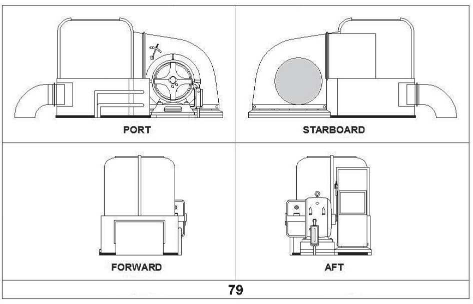
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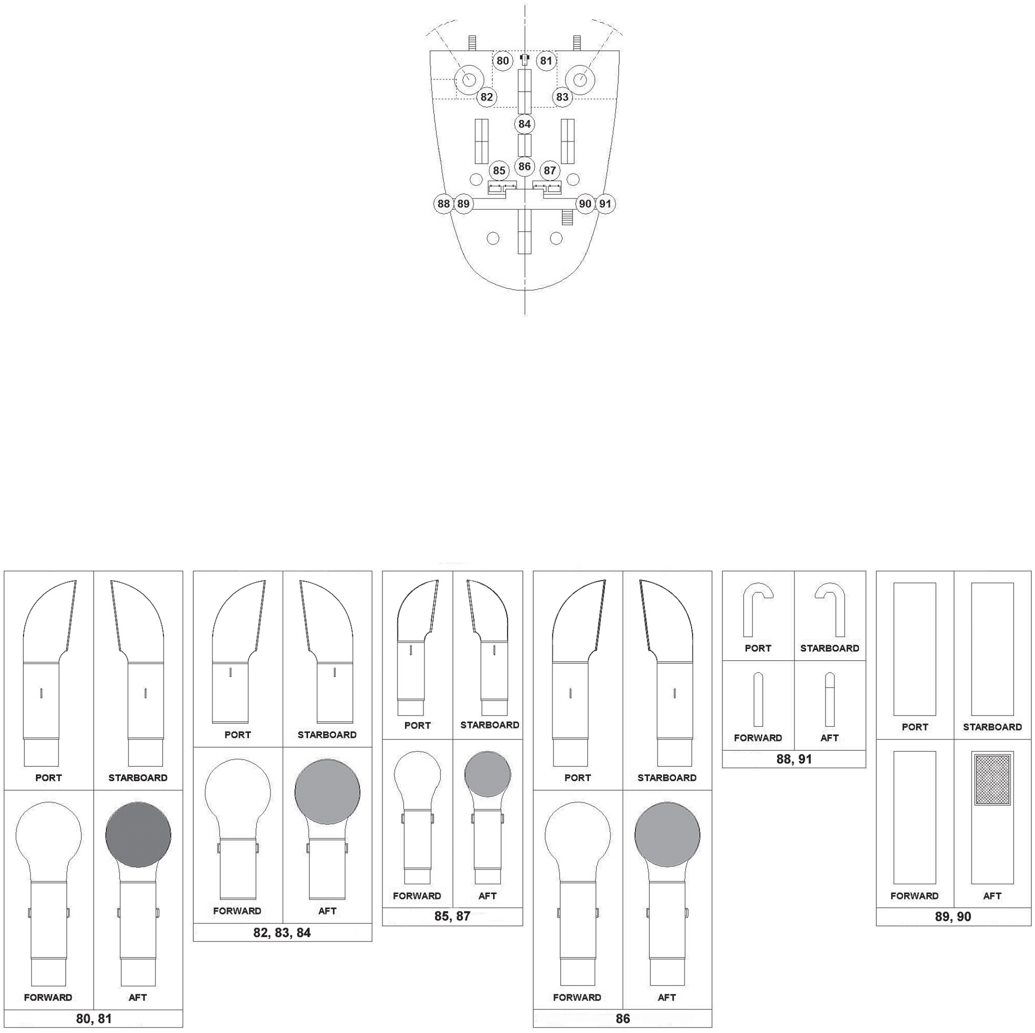

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Notes

1. Since *Titanic* was to operate primarily in the moderate-to-cold climate of the North Atlantic, cooling the air being delivered was not a consideration.
2. Although the majority of cowl vents seen on *Titanic* functioned as uptake ventilators, most had their airflow mechanically assisted by fans rather than relying on natural ventilation alone.
3. Occasionally, these louvers were referred to in some sources as 'jalousies.' One such source are the notes Leonard Peskett took during an August 1911 crossing aboard *Olympic,* in which he refers to louvered panels in the stateroom doors as jalousies.
4. Brass grilles were installed along the deck level of many of the bulkheads in the public rooms as is seen in the photos, but these did not always provide forced ventilation. The grilles corresponding to a funnel casing where the air was brought through main trunks were active, but those along partitions and the ship's side merely provided natural ventilation between the paneling and the steel of the hull. Brass grilles can even be seen along the base of the buffet in the *à la carte* Restaurant, so it seems these were installed in areas for decorative continuity as well.
5. 'Vitiated air' was the term used in 1912 for air that was hot, foul, odorous, smoky, etc and which would need to be vented from a compartment.
6. Magnesia insulation was made primarily from magnesium carbonate, an inorganic, inert substance usually mixed with other materials which acted as a binder. The plastic mix could then be cast into sheets

or blocks, or molded into shapes such as cylindrical pipe coverings, and then dried. The optimum mix was found to be 85 per cent magnesia and 15 per cent asbestos fibers. A cement made from this same material was used to cover the joints between panels and could be troweled over irregular surfaces.

7. The wheeled leaf blowers used by groundskeepers are centrifugal fans.

8. 'Sirocco' is the name for a powerful, unrelenting wind that blows in the Mediterranean, and is the likely origin of the name adopted by the Davidson company. Today, 'sirocco fan' is a generally accepted term for a centrifugal fan.

9. 'Freeboard assignment' relates to how deeply a vessel may be loaded – or, ultimately, whether or not the Board of Trade would certify a vessel to operate at its designed draft. The Board of Trade survey, required of every new vessel, considered not only factors such as the ship's stability and reserve buoyancy, but also the physical means of preventing the entry of water into the hull. For this reason ventilator coamings in areas subject to boarding seas needed to be constructed of sufficient height and strength to meet this requirement.

10. These are more correctly termed 'bitts' aboard ship, but the original Harland & Wolff terminology has been preserved here. Their construction is covered in greater detail in the next chapter.

11. Some of the genuine Thermotanks on other ships were fitted with humidifiers.

12. These were also the areas not fitted with electric radiators.

13. These should not be confused with the glow lamps provided as 'night lights' in the First Class staterooms.

14. Through both his repeated use of the term throughout his notes, and from his final notation following his description of the heating and ventilation system, it is probable that due to the significant number of thermotank-type devices located about *Olympic*'s decks, Peskett simply assumed that these devices heated all of the First Class public rooms, but this assumption was incorrect – they were heated on the warm-air system through the ventilation trunks contingent with the boiler casings.

15. On *Titanic* these 'coaming lights' were round.

16. Though often use interchangeably, the terms 'stokehold' and 'boiler room' are not synonymous. The term 'stokehold' refers to the space in front of the boilers and below the gauge platform from which the furnaces are tended. Aboard *Titanic,* there were eleven stokeholds – one in Boiler Room No.1, and two in each remaining boiler room. Like the boiler rooms, stokeholds – or 'firing aisles,' as they were later known – were consecutively numbered 1 through 11 heading forward. When examining testimony given at the inquiries following the *Titanic* disaster, it will be found that many of the Firemen did not speak in terms of the boiler room in which they worked; instead, many of them referred to the number of the stokehold.

17. This escape trunk is discussed in Volume 2 of this book, in the chapter covering the Orlop Deck, Lower Orlop Deck and Tank Top.

Chapter 20

Anchors, Mooring and Warping Equipment

Stockless anchors

The patent stockless anchor was developed about 1850. Although dismissed at first, it was widely used from the turn of the twentieth century onward. Patent anchors were double-fluked as were the old style stock anchors. However, in the case of the patent design, the arms were pivoted upon the shank and could swing from 30 to 40° on either side. The palms were in the plane of the arms instead of at right angles, which meant that the flukes would bite no matter which one landed first. To ensure that the flukes were able to bite, the arms carried a projecting shoulder with a sharp edge at the crown which made contact with the bottom and threw the arms downward. In addition, stockless anchors were easily stowed in their hawse pipes as there were no stocks or projecting flukes.

Anchors were usually made of cast steel; the stocks, rings, pins, shackles, balancing bands and other fittings were usually of forged steel. Given that *Titanic* was an emigrant ship, per regulations it was required that a third anchor be installed to complement the side bower anchors. This was done by mounting a third (auxiliary) anchor, housed in a well in the Forecastle Deck at the forepeak abaft the stem. All three anchors and their chains were manufactured by the firm of Noah Hingley & Sons Ltd of Netherton, Dudley.

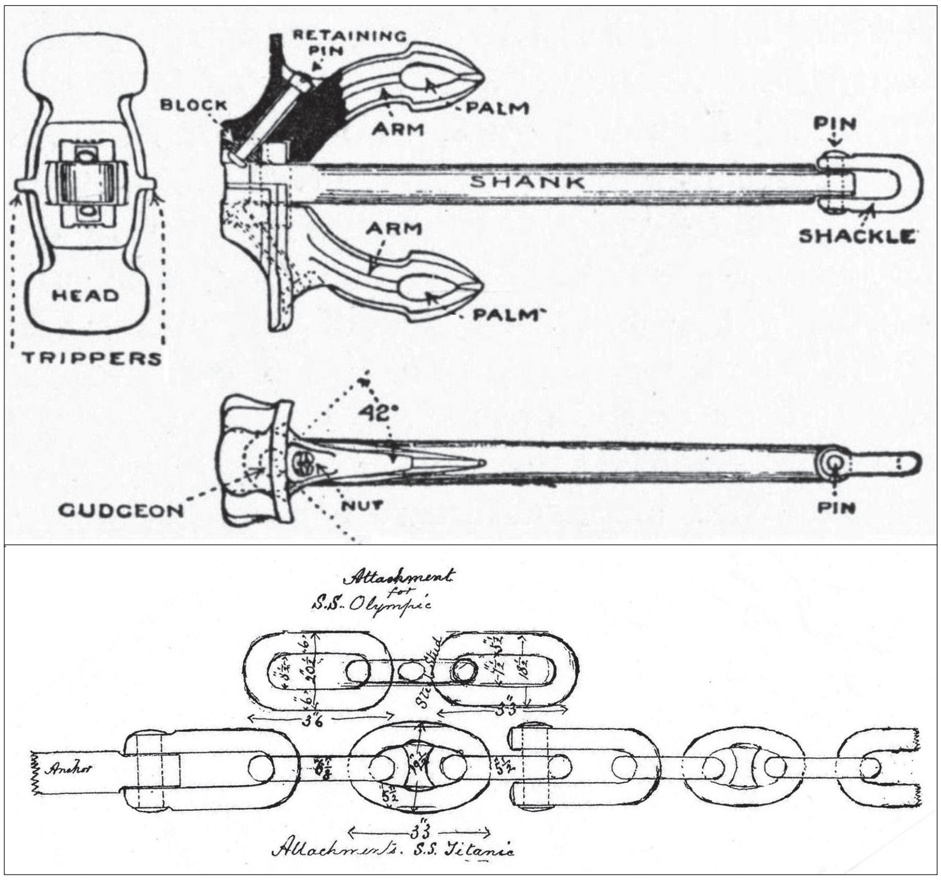
Titanic's anchors were the latest stockless Hall's Patent type. The center anchor weighed just over 15¾ tons[1] and was handled by a wire rope of 9½in circumference (2.66in diameter), 175 fathoms long. This was 'special extra-flexible' steel wire rope, with six strands of thirty-seven wires each, with a galvanized spindle spliced in each end. This hawser, together with the thimbles and splices necessary, was manufactured by Bullivant & Co. Ltd of London. It was guaranteed by the makers to withstand a breaking strain of 280 tons. At the request of the Board of Trade, one thimble and splice were tested to destruction at Cardiff in the presence of the Surveyor, with the result that the test specimen broke near the tail of the splice at a load of 289 tons.

The windlass for the center anchor cable was positioned within the ship beneath the Forecastle Deck at the forward end. The wire rope was wrapped around a large grooved drum which was driven by means of a worm gear driven by a shaft which was coupled through a dog clutch to one of the Napier windlass engines at a gear ratio of 120-to-1.

The wire rope was worked through an extra hawsepipe located in the stem; this hawsepipe contained a roller to alleviate stress and damage to the cable. The hawseport itself had a removable cover fixed in place over the opening when not in use. This anchor cable could also be used as a towing hawser when it was desirable to tow the ship from ahead, as was done when *Titanic* left Southampton docks, as well as serving as a mooring cable in the event the ship was required to tie up in midstream at a buoy, as was often the case for ships calling at the White Star Line's home port of Liverpool.

A strong crane (or 'davit' as it was sometimes called) was fitted directly aft of the center well for hoisting the anchor overboard. A removable door and portable railings were fitted into the sheer strake on the port side to accommodate this task. The crane was built on a system of bearings, allowing it to be easily rotated about on its shaft manually, which was stepped below on C Deck. Iron blocks and 2½in-circumference wire rope were supplied for lifting the anchor from its mounts and hoisting it over the side, after paying out sufficient cable to bring the thimble inboard and shackle it to the anchor. The crane had a radius of 16ft 6in and an outreach beyond the sheer strake of 6ft 0in, and could also be used to service the bower anchors if necessary.

The side bower anchors were housed in their hawse pipes in the usual manner. They weighed just over 7¾ tons apiece and were each attached to 3⅜in-diameter stud-link chains of 165 fathoms, making for a combined length of 330 fathoms weighing in at some 96 tons.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BLOCK
ARM
PALM
PIN
SHANK
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ARM
PALM
HEAD
TRIPPERS
42°
GUDGEON
NUT
PIN
Attachment for S.S. Olympic
Stud
3'6"
3'3"
Anchor
3'3"
Attachments. S.S. Titanic

Fig. 20-1 ***Titanic* Anchor and Chain** – The Hall's Patent Anchor was in widespread use in 1912. At top, a drawing of *Titanic*'s center anchor. At bottom, the stud-link sections forming the attachments between the anchor and the cable for *Olympic* and *Titanic*'s bower (side) anchors. *(Jonathan Smith collection)*

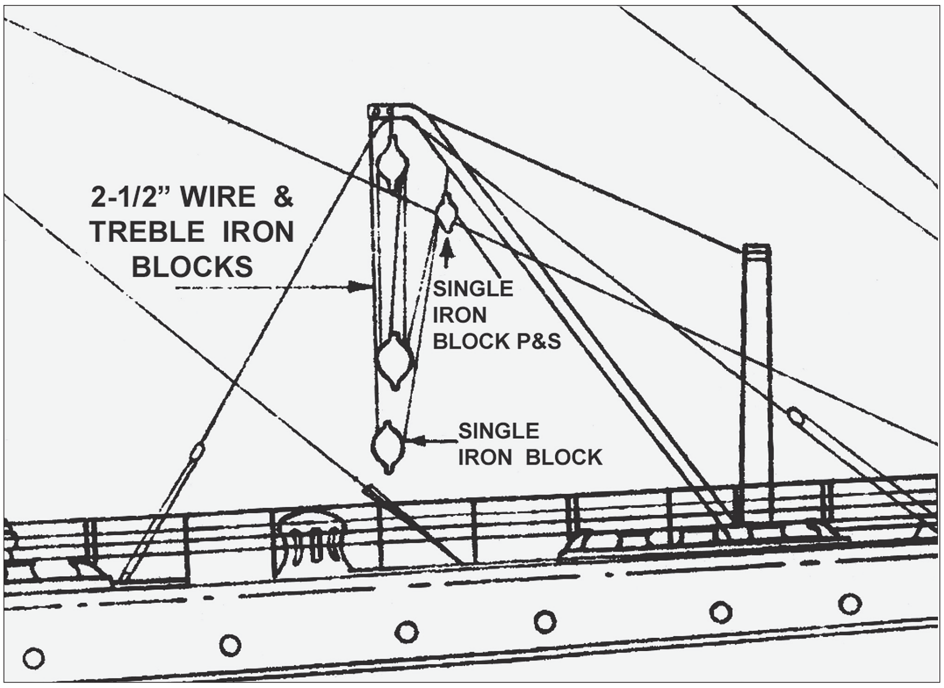
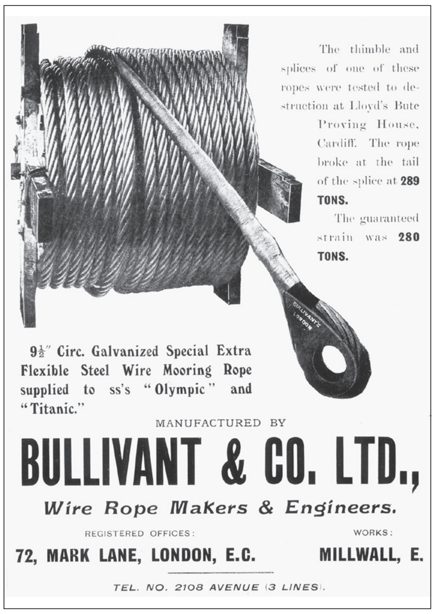

2-1/2" WIRE & TREBLE IRON BLOCKS
SINGLE IRON BLOCK P&S
SINGLE IRON BLOCK

Fig. 20-2 **Anchor Crane Rigging**. *(Illustration by Art Braunschweiger based on original H&W Rigging Plan)*

Technical specifications for *Titanic*'s anchors are as follows:

Center Anchor: one Hall's Patent Stockless anchor with cast steel head
316cwts, 0qrs., 0lb or 15.80 Long Tons
Dimensions: approx. 17ft long by 10ft 3in wide

Bower Anchors: two Hall's Patent Stockless anchor with cast steel heads
Starboard: 157cwts, 3qrs, 8lb; or, 7.89 Long Tons
Port: 156cwts, 0qrs, 14lb; or, 7.81 Long Tons



The thimble and splices of one of these ropes were tested to destruction at Lloyd's Bute Proving House, Cardiff. The rope broke at the tail of the splice at **289 TONS.**

The guaranteed strain was **280 TONS.**

BULLIVANT'S
LONDON

9½″ Circ. Galvanized Special Extra Flexible Steel Wire Mooring Rope supplied to ss's "Olympic" and "Titanic."

MANUFACTURED BY

BULLIVANT & CO. LTD.,

Wire Rope Makers & Engineers.

REGISTERED OFFICES:
72, MARK LANE, LONDON, E.C.

WORKS:
MILLWALL, E.

TEL. NO. 2108 AVENUE (3 LINES).

Fig. 20-3 **Bullivant & Co. Advertisment** – Bullivant & Co. advertisement highlighting the center anchor cable of *Olympic* and *Titanic*. *(*The Shipbuilder/ *Authors' collection)*

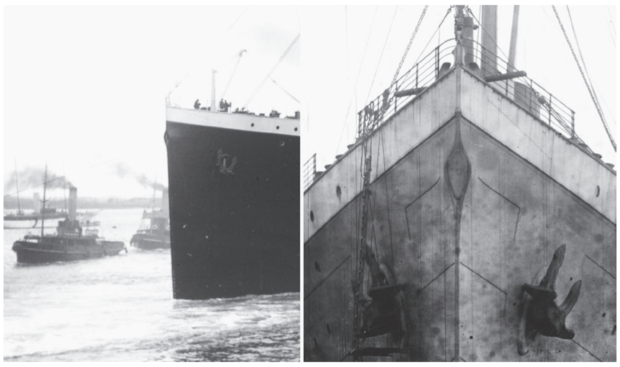


Fig. 20-4 **Hawse Port Cast Into Stem** – At left, a detail from an image of *Titanic* departing Southampton. The cast-steel hawse pipe fitted into the stem is seen here with the wire rope hawser led through it and being used by the tugs to assist in towing the ship out of the White Star Dock. At right, *Titanic* in dry dock. The hawse pipe is seen here covered with its plug. *(Both images from authors' collection)*

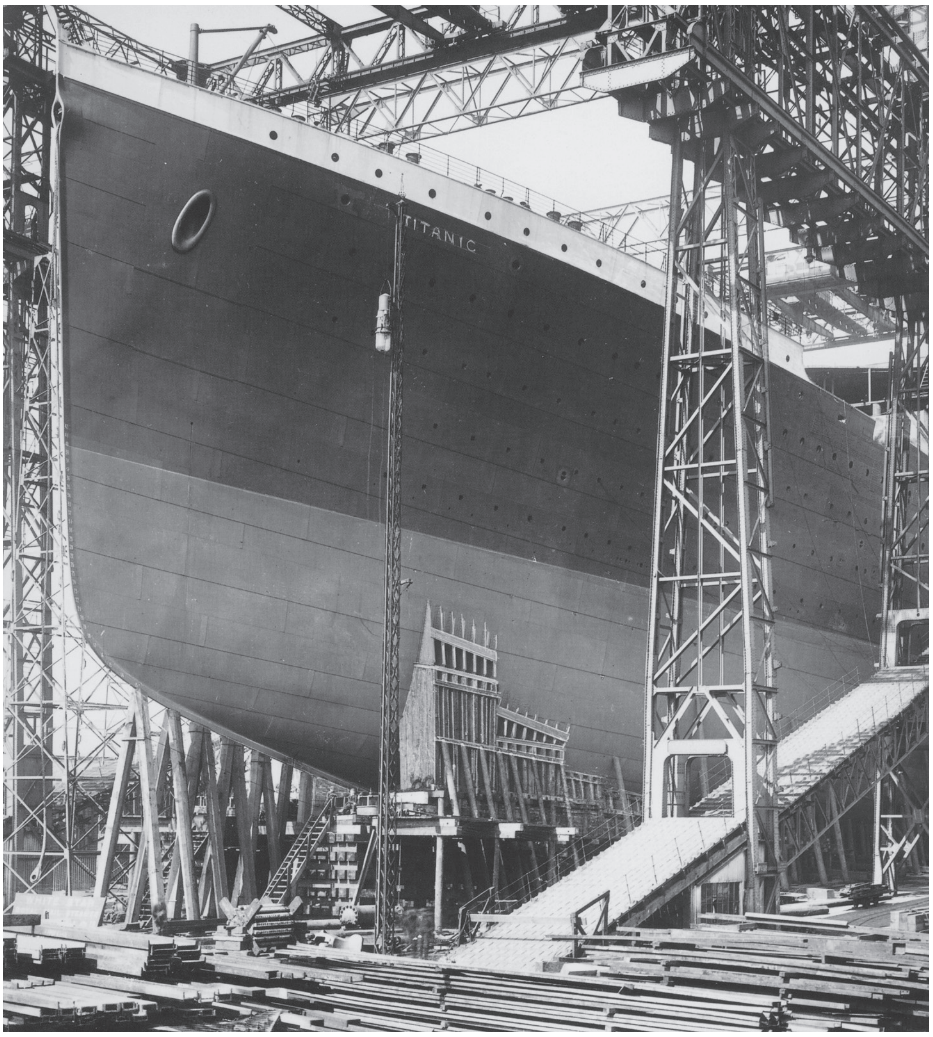


Fig. 20-5 ***Titanic* in Construction Berth with Center Anchor Cable in View** – *Titanic* as she lay in her construction berth. The center anchor cable is seen here hanging out of the hawse pipe in the stem casting prior to being fully wound onto the windlass for the first time. Laying beneath the forefoot just forward of the hydraulic ram at the head of the ways, a large wooden spool can be seen; this was likely the spool on which the recently installed cable was delivered to the yard. *(H&W/Authors' collection)*

The center anchors were the largest in the world at the time, and *Olympic*'s was put on display at the Engineering and Machinery Exhibition at Olympia, London before being delivered to Harland & Wolff. Recently, a rare interview with one of the men who helped create the mammoth anchors for *Olympic* and *Titanic* was uncovered in the archives of the *Black Country Bugle*. The interview, conducted in 1976, was the personal account of Mr W.G. Edwards, a former Hingley's worker, and in this interview he described

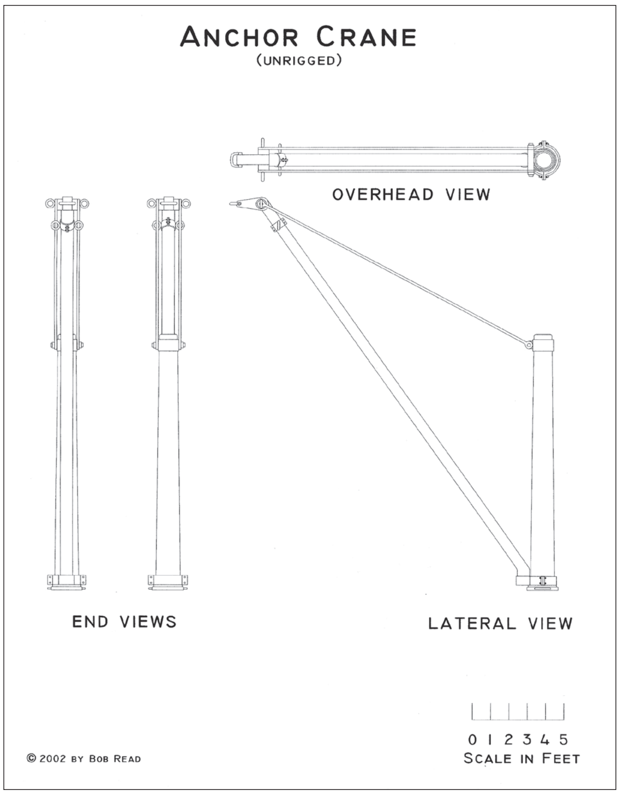


Fig. 20-6 ***Titanic*'s Anchor Crane**. *(Illustration by Bob Read)*

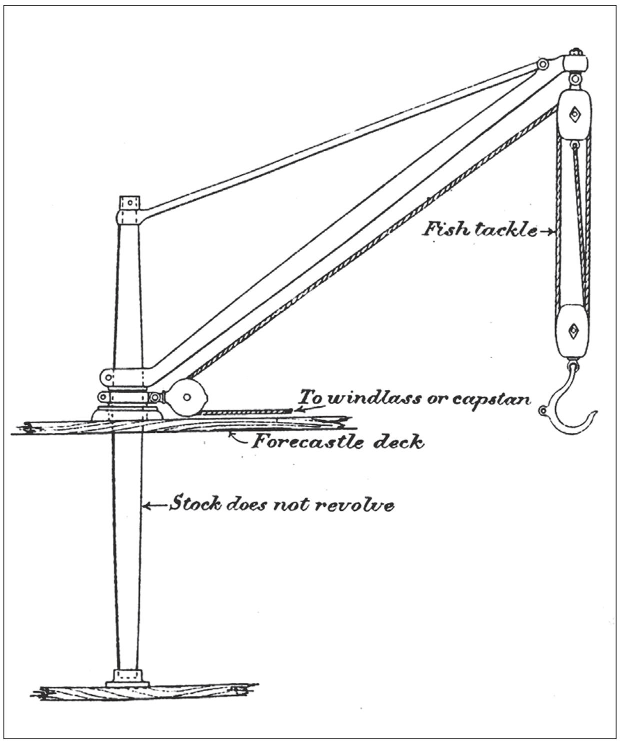


Fig. 20-7 **Stepping of Davit Crane** – *Titanic*'s anchor crane was stepped at the Shelter Deck (C). This figure illustrates the principal structural features of an anchor crane similar to *Titanic*'s. The one on *Titanic* had no machinery to rotate it; this was done manually by means of guys. In this illustration, it will be noticed that a line is shown rigged to go to a windlass or capstan. Although the base of *Titanic*'s crane had two eyes at this location that could conceivably have been used to rig a block, it is unknown whether these eyes were used in this manner. This also does not show how the anchor crane was rigged for lifting on *Titanic* when in use, as shown in the previous illustration.

the process of testing and shipping *Olympic*'s[2] center anchor:

> *The parts were then transported to 'Lloyds Proving House' to be assembled under the supervision of Mr Norman [the head fitter]. I [the writer] took part in this operation. The anchor now had to be lifted onto the Test Bed and a stronger chain had to be fitted to the crane which had to be ballasted with pig iron to counterbalance the weight of the anchor. Steam was raised to a critical point for the operation. Henry Green was the supervisor at the Proving House and Job Garrett was in charge of testing.*
>
> *Having passed all tests, it was taken outside and painted white. Now came the time to transport the anchor to the ship-building yards of 'Harland & Wolff' in Belfast. The big transporters in those days were 'Bantocks' and they arrived with a huge wagon and eight horses. The wagon was backed up and it was loaded on. The horses were unhitched and replaced in the shafts by six of 'Hingleys' own horses. These were massive animals – each weighing over a ton. In front of these the 'Bantock' horses assembled in two single files on a long chain. They tugged the wagon up the incline from the Proving House where the 'Bantock' horses fanned out either side, allowing 'Hingleys' horses to pull the wagon across the road to the entrance of 'Lee's Coalyard'. The wagon was then slowly turned to face up to Dudley. All the horses then took the strain and to shouts of encouragement they slowly hauled their heavy load to the railway goods yard for the next stage of its journey.*

This engaging account does much to illustrate what manufacturing and road transportation was like in 1912, before the advent of hydraulic equipment and heavy diesel machinery.

Titanic also carried two Trotman's iron kedge anchors with external stocks. The purpose of kedge anchors was to warp a ship round in tight spots, to assist if the ship ran aground, to act as a spring and to serve in a number of other situations where an auxiliary anchor could be utilized. The kedge had to be carried out by a ship's boat to a predetermined location and released. The after kedge anchor was more properly termed a 'stream anchor'.[3] In cases of grounding on a soft seabed, the stream anchor was only intended to hold the ship in its position until a bower anchor could be carried out or until a tug or other ship could assist. For instance, if the ship were to run aground by the bow, the stream anchor would be carried out off the stern to keep the aft end from swinging in the current.

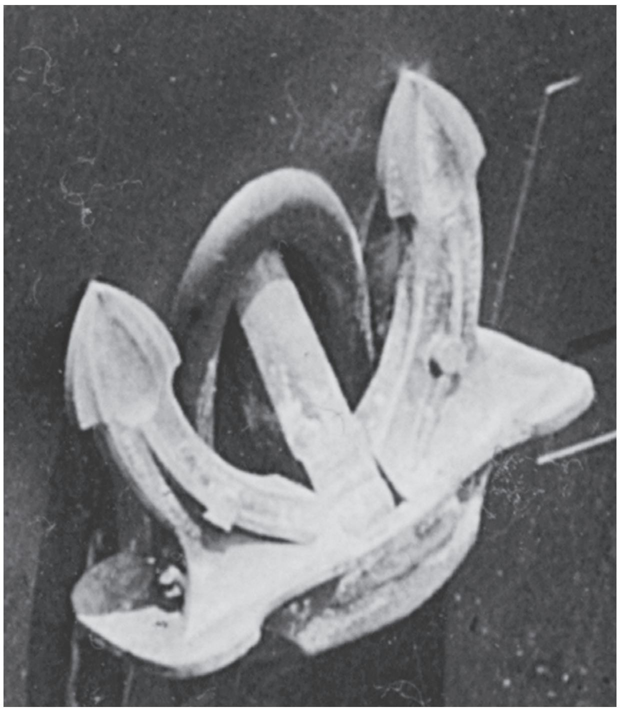


Fig. 20-8 ***Olympic*'s Starboard Anchor** – *Olympic*'s starboard anchor hove up into the hawse pipe. *(Peter Davies-Garner collection)*

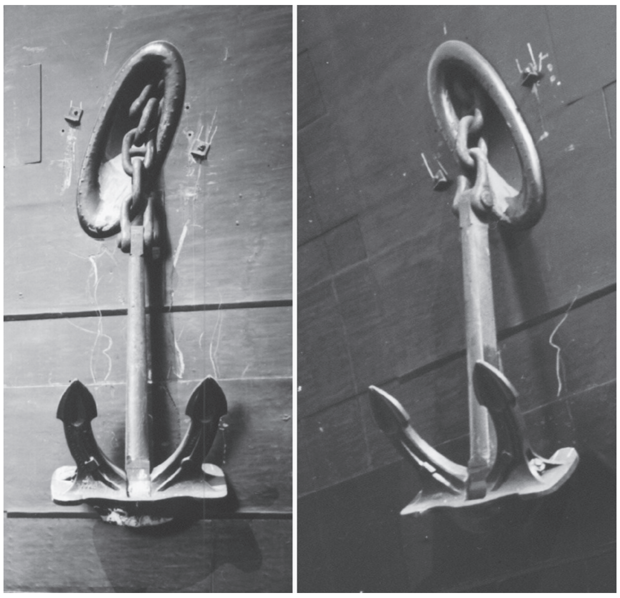


Fig. 20-9 ***Olympic*'s Port and Starboard Anchors** – *Olympic*'s port and starboard anchors with slack in the cable, permitting a view of the shank of each anchor and the retention lugs fitted to the shell plates. Notice the light paint shade within the hawsehole in comparison to the black of the hull. This would indicate that the hawsehole was not painted red as some artists' impressions show.

The forward kedge and stock, weighing a little over half a ton, was fastened to the Forecastle Deck on the starboard side just aft of the breakwater. The after stream anchor was stowed on the Poop Deck just starboard of the centerline of the ship, strapped to the aft rail and weighing about 1¼ tons. These anchors had a removable stock for ease of storage. As a design feature in the Trotman's anchors, the heads were designed to swivel on the shank to provide greater biting power to the ground.

Technical specifications for the Trotman's kedge anchors supplied to *Titanic* are as follows:

One Trotman's kedge anchor with iron stocks: 25cwts, 2qrs, 27lb; or, 1.29 Long Tons
One Trotman's kedge anchor with iron stocks: 12cwts, 3qrs, 7lb; or, 0.64 Long Tons

Anchor cables

Anchor chains are always referred to as 'cables', probably because in earlier practice a cable-laid rope was used to secure the anchor. Chain cables were made of wrought iron because of its ductility, which resisted shocks and was conducive to being welded[4], in which characteristics it excelled over period steel. Bars were rolled to the size required for the links; chain 'bolts' were sawed from the bars as they came from the rolls while still hot. Their ends were sawed, or 'scarfed', at an angle of 30° and they were then bent to the form of the link by a machine before the original heat from the rolls dissipated. The ends were left sufficiently open to allow the link being formed to be threaded through the one previously made. Once threaded into place, the scarfed ends of the link were closed down upon each other and then heated to welding temperature after which the weld was completed.

The shape to which the link had been bent permitted the insertion of a stud. This was a cylindrical bar spanning the center of the link from side to side, its principle purpose being to prevent the cable from kinking and to ensure that the links fed properly onto the cable wheels – it did not add strength to the chain. The links were closed down on the stud while hot and the contraction in cooling held the stud in place. The studs were drop-forged from mild steel. The Anchors and Cables Act provided that:

> The maker or dealer in anchors and cables may not sell or contract to sell – nor shall any person purchase or contract to purchase – for the use in any British ship any anchor or cable exceeding in weight 168lb which has not been previously tested and stamped in accordance with the Cables and Anchors Act.

Each length of chain which had been so proven at a testing-house bore on a link the test mark, and also the

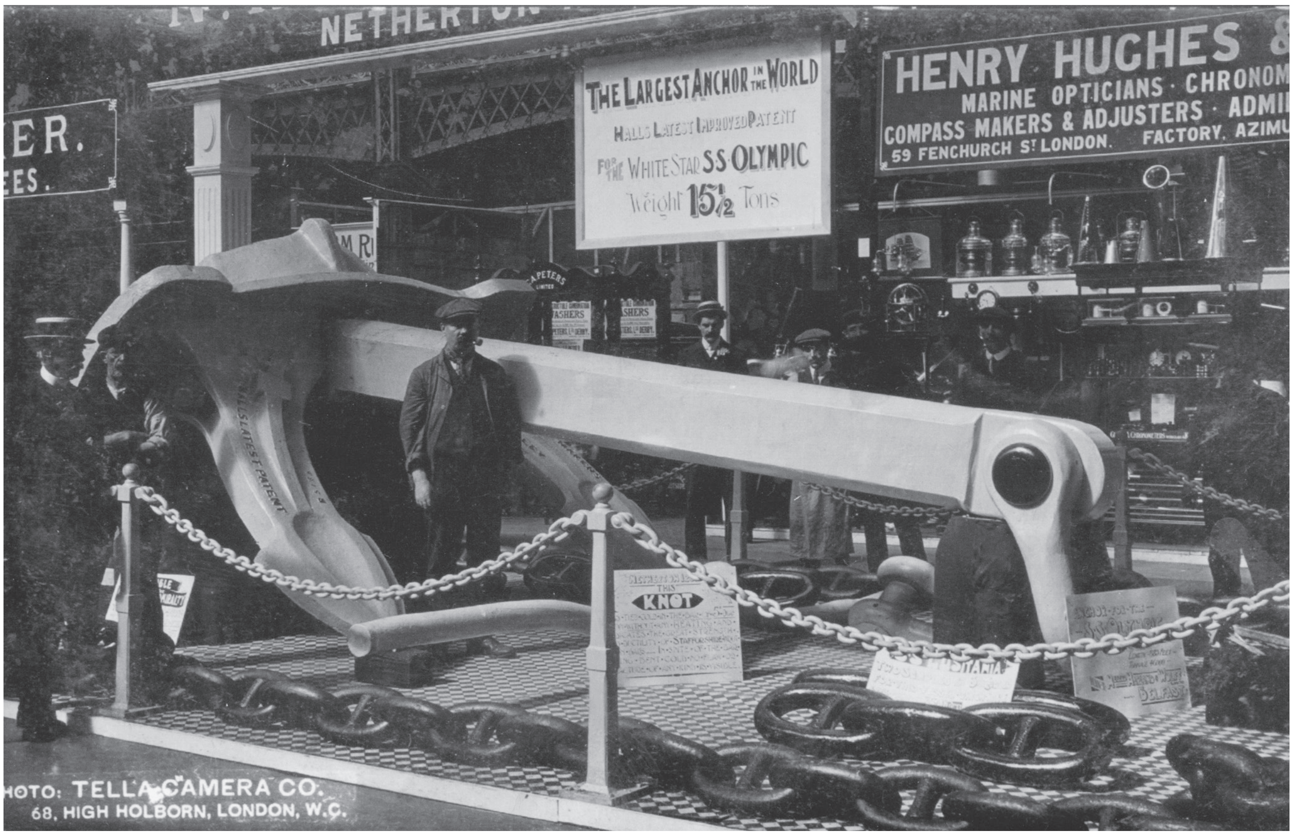

NETHERTON
ER.
EES.
THE LARGEST ANCHOR IN THE WORLD
HALLS LATEST IMPROVED PATENT
FOR THE WHITE STAR SS OLYMPIC
Weight 15½ Tons
HENRY HUGHES &
MARINE OPTICIANS · CHRONOM
COMPASS MAKERS & ADJUSTERS · ADMI
59 FENCHURCH St LONDON. FACTORY, AZIMU
HALLS LATEST PATENT
KNOT
HOTO: TELLA CAMERA CO.
68, HIGH HOLBORN, LONDON, W.C.

Fig. 20-10 ***Olympic*'s Anchor on Display** – *Olympic*'s center anchor on display in 1910 at the Engineering and Machinery Exhibition at Olympia, London. This anchor was the largest in the world at the time, and Hingley, the manufacturer, was quite proud of it.
(R. Terrell Wright collection)

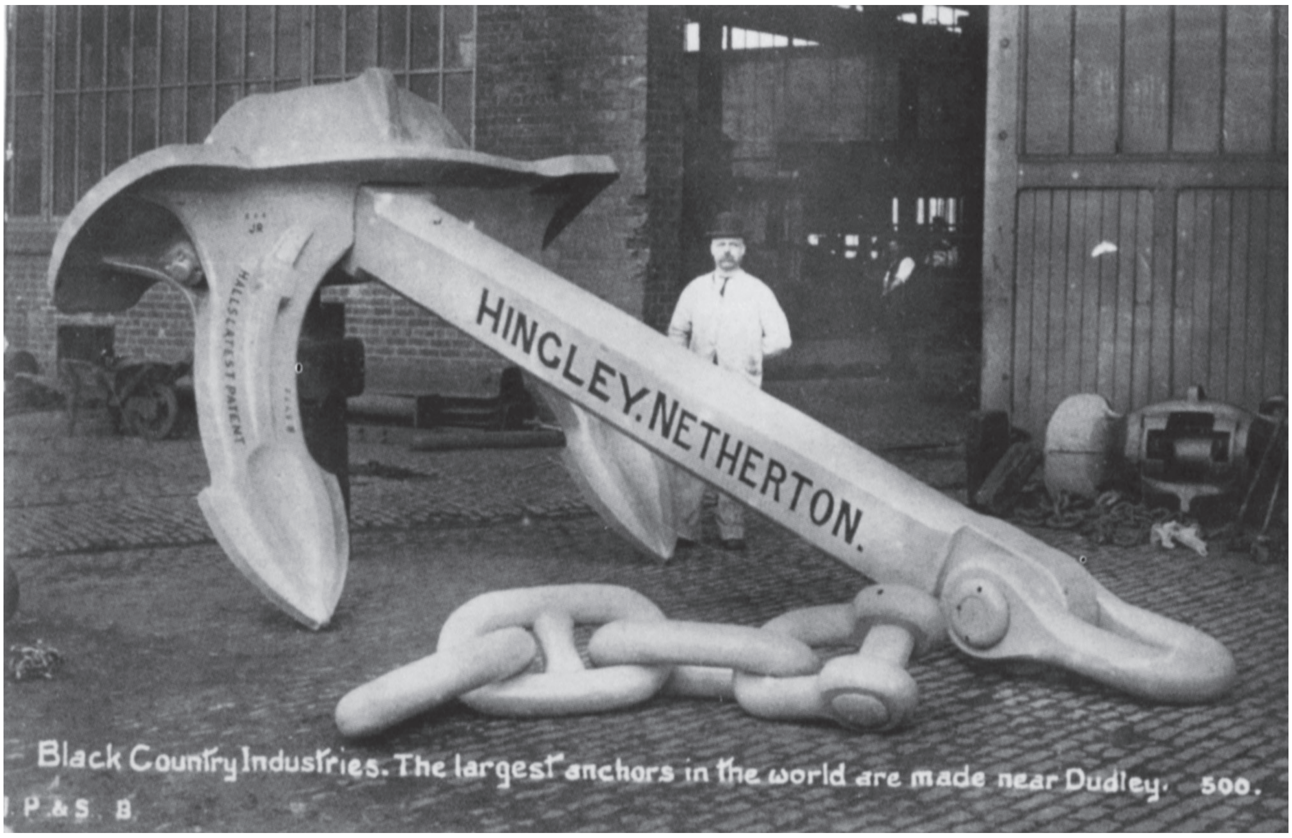

HALLS LATEST PATENT
HINGLEY. NETHERTON.
Black Country Industries. The largest anchors in the world are made near Dudley. 500.
J.P.&S.B.

Fig. 20-11 ***Titanic*'s Center Anchor** – In this view, Jack Holloway of Lloyd's Proving House stands behind *Titanic*'s anchor outside the Proving House following assembly and painting. Due to the lack of publicity from the White Star Line, the Hingley company painted 'HINGLEY. NETHERTON' on the anchor's shank. Of the three center anchors supplied to the *Olympic*-class ships, *Titanic*'s was the only one to be lettered in this manner.

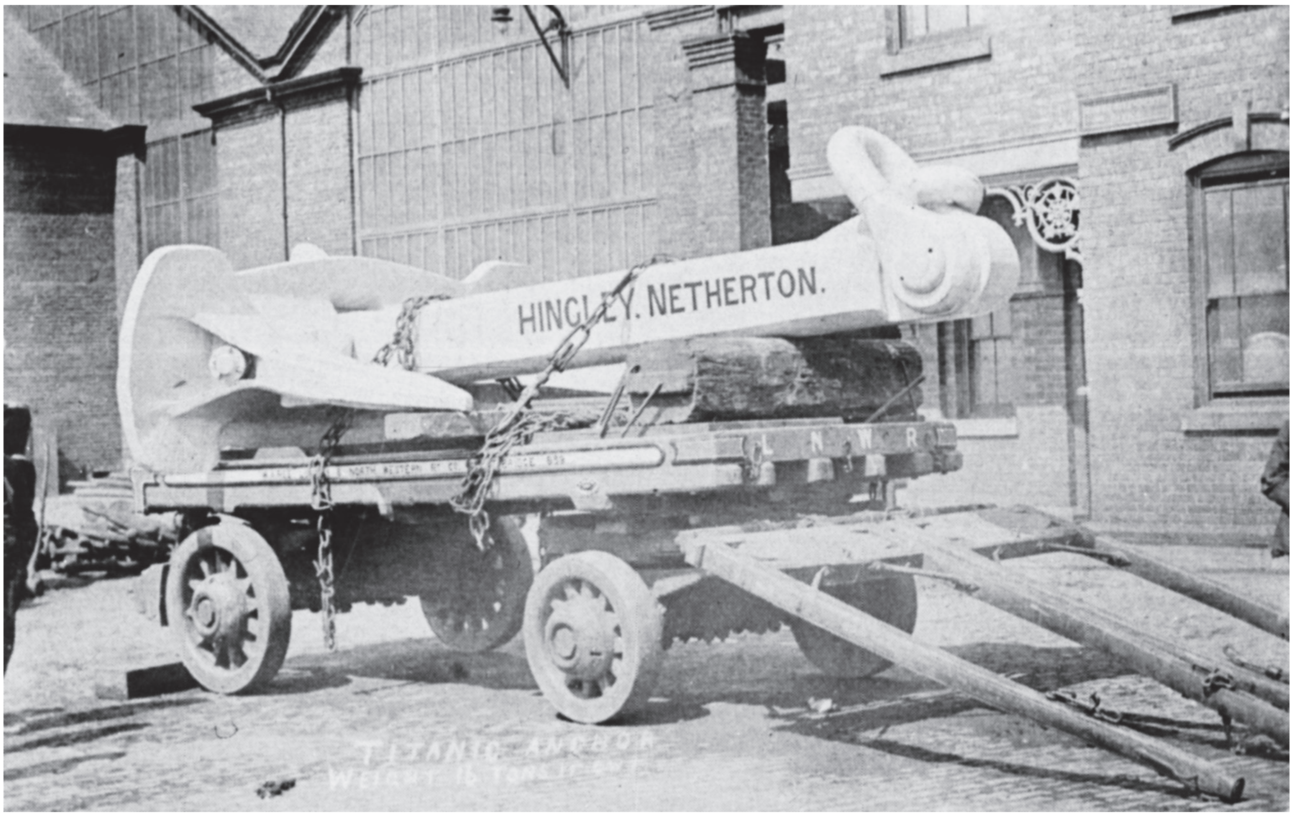


Fig. 20-12 **Anchor on Dray** – *Titanic*'s center anchor ready for transport, with the manufacturer's name painted on the anchor's shank. This photograph was taken outside the Lloyd's Proving House, which adjoined the foundry buildings to the left. The anchor was assembled and tested at the Proving House, after which it was painted white and readied for transport.

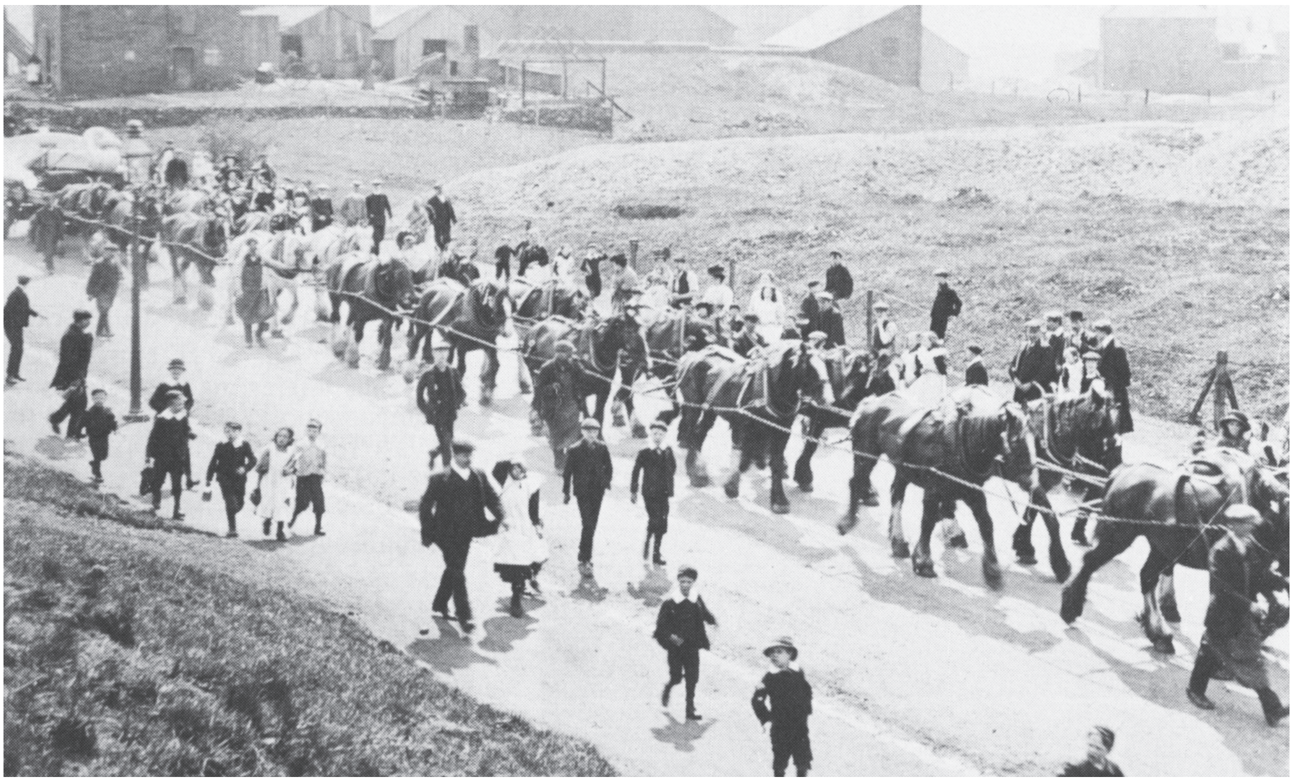


Fig. 20-13 ***Titanic*'s Center Anchor Being Transported by Horse Team** – In this iconic image taken on Sunday April 30, 1911, a team of twenty Shire horses hauls *Titanic*'s anchor out of the Hingley works on the beginning of its long journey to Belfast. Here the anchor, being transported by the local haulage firm W. A. Ree, is being pulled up the dirt road on Primrose Hill toward the Northfield Road on its way through Netherton and on to Dudley. From there it will be transported by the London & North Western Railway to the coastal port of Fleetwood in Lancashire where it will be transported across the Irish Sea by the North Lancashire Steam Navigational Company steamer *Duke of Albany* to Donegall Quay in Belfast.

letters 'BT' and a crown. Anchors had to bear similar tests according to their weight without the stock. Every anchor manufacturer was required to mark, in legible characters and both on the crown and also on the shank under the stock his name or initials, and was in addition to mark on the anchor a progressive number and weight of the anchor.

The chains were stowed in a special hold called the chain locker, located below the windlasses. They fed into the chain locker through steel chain pipes that were fitted vertically through the decks ending at the top of the chain locker via a cast-steel ring. The chain locker was built of steel on the forward side of the collision bulkhead between the Orlop Deck and the Upper Deck (E). The floor of the locker was supported between the Orlop Deck and floors by a center-line partial bulkhead which stopped about 6ft 0in below the beams at the top of the locker. The forward end and sides of the locker were caulked watertight. All the edges of gussets and stiffeners inside were fitted with chafing battens. The sides of the chain locker were fitted with 6in x 2in sparring above the Middle Deck (F). The bottom of the locker was covered with 3in wood deals laid over 4in of concrete. The ends of the cables were fastened by joining shackles to eye plates attached to the centerline bulkhead.

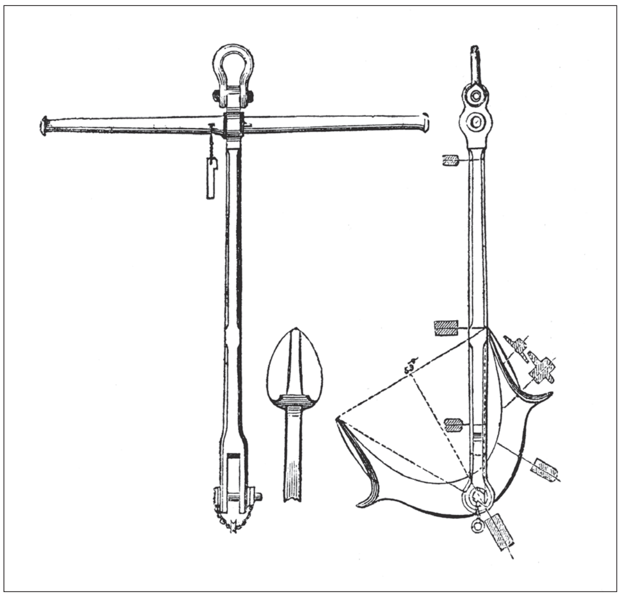


Fig. 20-14 **Trotman's Anchor** – A Trotman's anchor as seen in a catalogue of Admiralty contracts. This catalogue dates from the very late 1800s, but the design would have changed little, if at all, by the time *Titanic* was fitted with these.

Technical specifications of cables are as follows:

3⅜in-diameter cable (stud-link chain); length 165 fathoms; weight 960cwts, 0qrs, 8lb
3⅜in-diameter cable (stud-link chain); length 165 fathoms; weight 959cwts, 2qrs, 10lb

2 attachments each consisting of 2 open links and 1 stud link; weight 20cwts, 1qr, 7lb
1 attachment consisting of 2 open links, 1 stud link and 1 shackle; weight 20cwts, 2qrs, 9lb

Spare Gear:

1 End Shackle; weight 4cwts, 2qrs, 1lb
2 Joining Shackles; weight 5cwts, 2qrs, 9lb

Anchor hawse pipes

The hawse pipes were so placed as to give practically a straight lead for the cables from the windlasses. The cables passed directly through the vessel's bow plating from the Forecastle Deck. The hawsehole was merely a cast-steel ring for all intents and purposes. The mouths were massive and strong, for when the vessel was at anchor with the cable leading astern, they were subjected to severe stress, and sometimes suffered intense shocks and vibratory effects. They

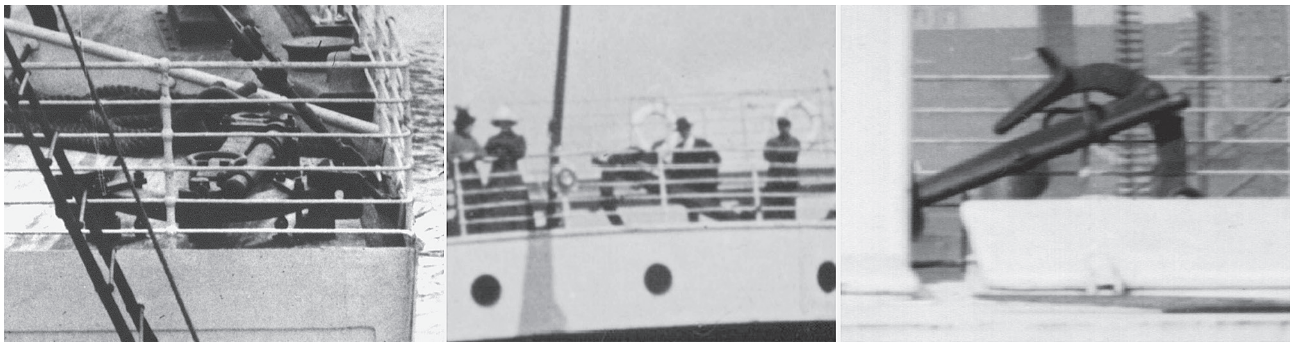


Fig. 20-15 **Trotman's Anchor in Place** – At left, the Trotman's kedge anchor mounted on the starboard side of *Titanic*'s Forecastle Deck. At center, *Titanic*'s second kedge anchor mounted to the railing of the Poop Deck with iron straps; at right, a view looking aft on *Olympic*'s Poop Deck showing the same anchor. *(Left image Father Browne photograph; center image Peter Davies-Garner collection; right image authors' collection)*

were fitted with an easily curved lower lip, since it was this part that suffered the most pressure from the cable. In considering the movement of the anchor as it was pulled into the hawse pipe, it was evident that the lower part of the latter received a severe nip, because when the anchor – hanging vertically – reached the pipe, it could not enter until it was forced up into line by the pressure of its contact with the lower lip of the pipe and by the pull of the cable. The anchors were pulled up tight in the pipes so that their projecting flukes could not move and chatter when struck by the waves. To ensure that the anchors were held tight

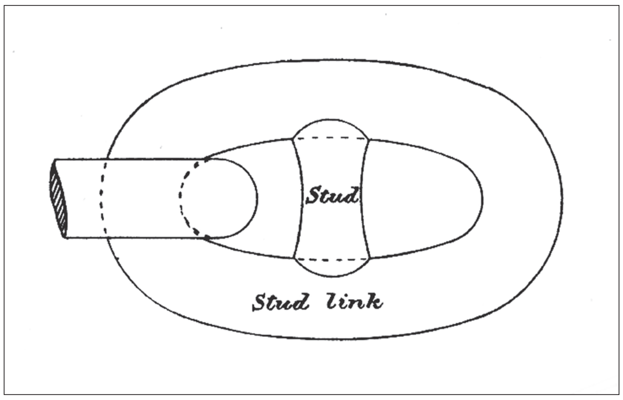


Fig. 20-16 **Stud Link**. *(*Practical Shipbuilding*)*

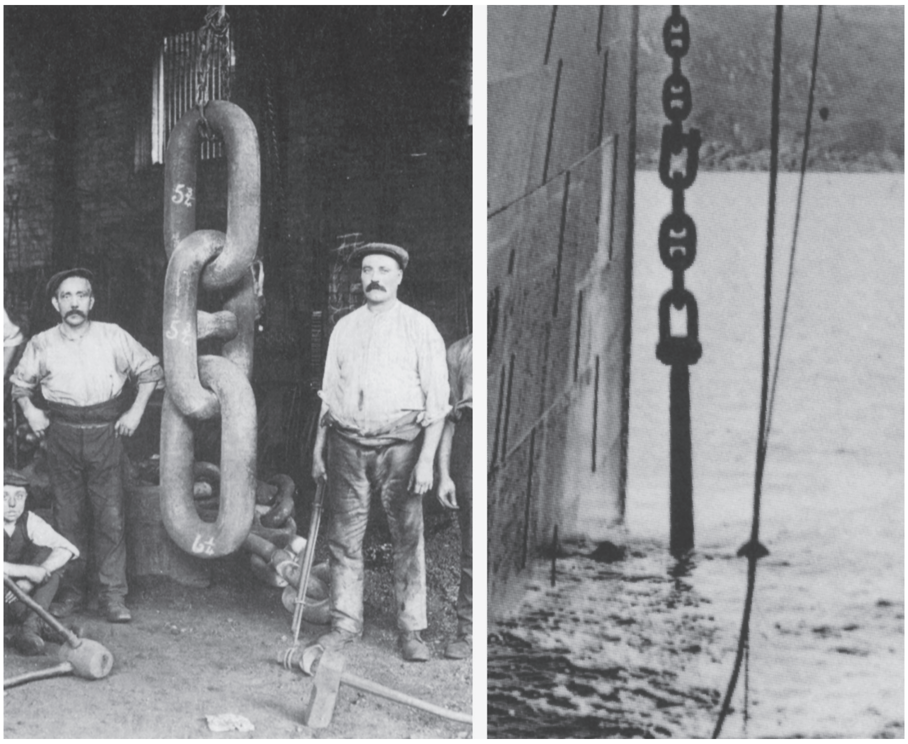


Fig. 20-17 **Stud Links at Hingley's** – At left, three links intended for the bower anchors of either *Olympic* or *Titanic*, photographed at Noah Hingley & Sons along with some of the men who made them. The links in the left image are of enormous size, far heavier than the rest of the cable, which was made of links only 3⅜in diameter. The image at right, of the starboard anchor being raised at Queenstown, shows the heavier links in place between the anchor and the cable itself. *(Left image Ray Lepien collection; right image Father Browne photograph from authors' collection)*

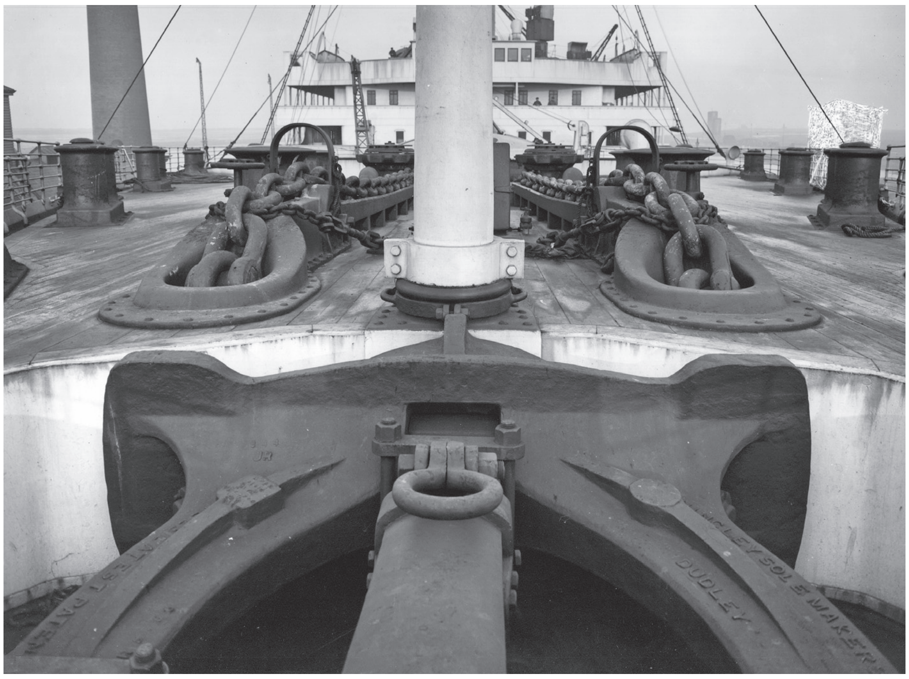


Fig. 20-18 **Center Anchor on *Olympic*** – A view looking aft from the prow of the *Olympic* during her 1912-13 refit. The manufacturer's name cast into the anchor can be seen here. Also visible are some specification numbers raised on the surface, and located on the square protrusion on the anchor are stamped some Board of Trade numbers. *(H&W/Authors' collection)*

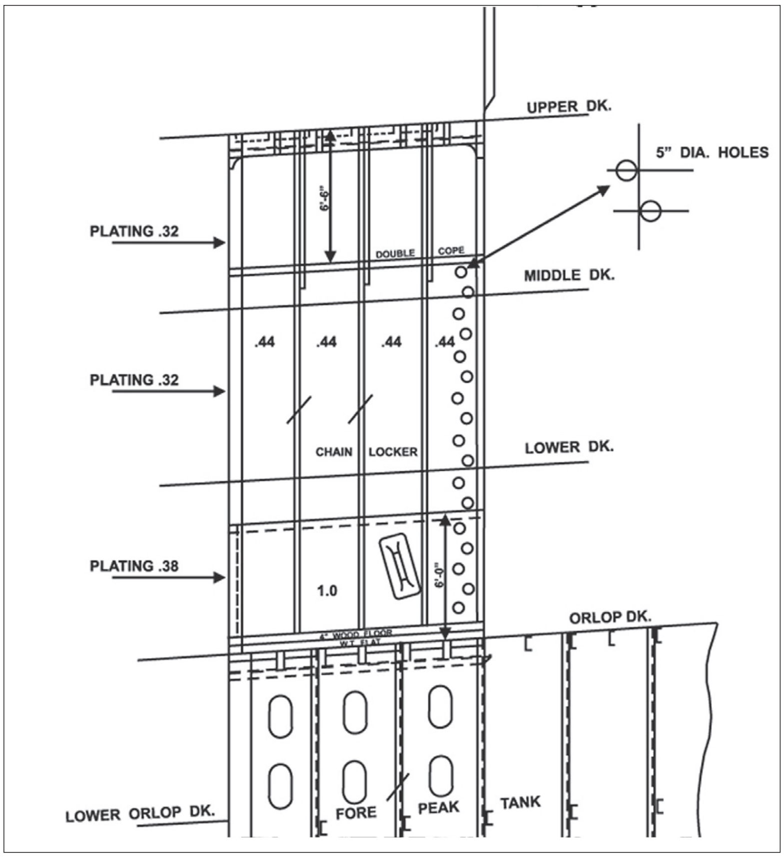


Fig. 20-19 **Profile view of Chain Locker** – *Titanic*'s chain locker, as illustrated in a drawing detailing the construction of Watertight Bulkhead A.

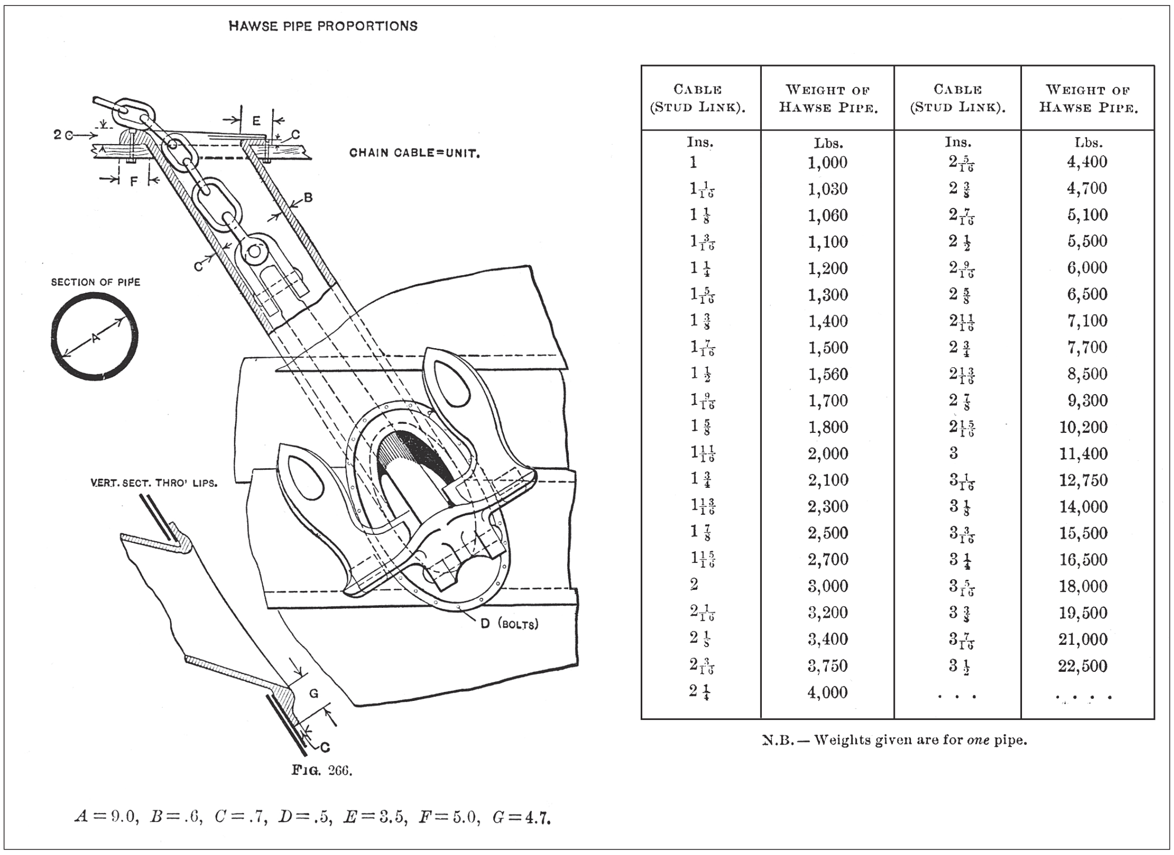
against the shell plating, external angle lugs were fitted on the shell to make contact with the flukes.

The hawsepipes were made of steel castings. The outer ends were connected to the shell by rivets passing through their lips; and, to give a rigid foundation and attachment, the shell plating was locally doubled. The top end of the pipes which passed through the Forecastle Deck were not secured to the deck, but merely pierced it, and fitted over them was a cast-steel, slab-like frame which *was* attached to the deck. Care was observed to secure the watertightness of the Forecastle Deck where pierced by the pipes, since leaking was not unusual at this part, and was difficult to correct. *Titanic* had plate covers for the hawse pipes so that when she plunged bow-under, the water could not rush up the pipes and flood the forecastle. Steam lines were supplied on the Shelter Deck level (C) to blow out any accumulation of ice in the hawsepipes in cold temperatures.

Deployment equipment

The anchor cables exited from the chain pipes at the base of the windlasses on their forward sides, took a turn around the cable wheels[5] on the windlasses and ran horizontally along the top of teakwood chain races, which resembled elevated ramps in appearance. At the forward ends of the chain races the cables entered the hawse holes located abaft the center anchor well. The forward ends of the races were fitted with locking and safety features. The anchor cables could be secured to the deck at the forward end of each race with 'slip-stoppers;' these were smaller chains which attached to heavy pad eyes mounted on the deck. These slip stoppers were used for securing the chain when riding at anchor. When used in this manner they were termed 'riding stoppers', and had to be extra strong as it was intended that the entire strain of the cable be borne by the stoppers rather than by the windlass itself. Stoppers were also used to tightly hold the anchors in their housings while stowed. When used in this fashion, the they were referred to as 'housing stoppers' as they were fitted with screw turnbuckles for drawing the anchor close up into the hawse pipe.

Another device fitted into the fore end of each chain races was a 'compressor'. These were installed into the cast-steel blocks situated at the very forward end of the chain races. They were primarily designed to control the chain by catching it link by link as it came in, so that if it slipped on the cable wheel or if anything else went wrong inside, no harm would be done. Each horizontal link, as it came in, dropped down abaft the lip of the heavy block, while the vertical link next forward of it dropped into a slot in the top of the same block. A tongue would rise up and lock every horizontal link, producing the characteristic clanking sound associated with the raising of a ship's anchors.



Cable (Stud Link).	Weight of Hawse Pipe.	Cable (Stud Link).	Weight of Hawse Pipe.
Ins.	Lbs.	Ins.	Lbs.
1	1,000	$2\frac{5}{16}$	4,400
$1\frac{1}{16}$	1,030	$2\frac{3}{8}$	4,700
$1\frac{1}{8}$	1,060	$2\frac{7}{16}$	5,100
$1\frac{3}{16}$	1,100	$2\frac{1}{2}$	5,500
$1\frac{1}{4}$	1,200	$2\frac{9}{16}$	6,000
$1\frac{5}{16}$	1,300	$2\frac{5}{8}$	6,500
$1\frac{3}{8}$	1,400	$2\frac{11}{16}$	7,100
$1\frac{7}{16}$	1,500	$2\frac{3}{4}$	7,700
$1\frac{1}{2}$	1,560	$2\frac{13}{16}$	8,500
$1\frac{9}{16}$	1,700	$2\frac{7}{8}$	9,300
$1\frac{5}{8}$	1,800	$2\frac{15}{16}$	10,200
$1\frac{11}{16}$	2,000	3	11,400
$1\frac{3}{4}$	2,100	$3\frac{1}{16}$	12,750
$1\frac{13}{16}$	2,300	$3\frac{1}{8}$	14,000
$1\frac{7}{8}$	2,500	$3\frac{3}{16}$	15,500
$1\frac{15}{16}$	2,700	$3\frac{1}{4}$	16,500
2	3,000	$3\frac{5}{16}$	18,000
$2\frac{1}{16}$	3,200	$3\frac{3}{8}$	19,500
$2\frac{1}{8}$	3,400	$3\frac{7}{16}$	21,000
$2\frac{3}{16}$	3,750	$3\frac{1}{2}$	22,500
$2\frac{1}{4}$	4,000	. . .	. . . .

N.B. — Weights given are for *one* pipe.

$A = 9.0,\ B = .6,\ C = .7,\ D = .5,\ E = 3.5,\ F = 5.0,\ G = 4.7.$

Fig. 20-20 **Hawse Pipe Illustration** – A hawse pipe and anchor unit from a period naval construction source. Though not exactly the same design as used in the *Olympic*-class liners, the various parts which make up the unit as a whole were commonplace at the time. The measurements were important as these would change proportionately with the size of the hawse pipe and its fittings. The standard weight of the hawse pipe assemblies are specified to the right.

On *Titanic*, the compressors were fitted with heavy coiled springs designed to absorb the shocks that came with raising the chains and as well as riding at anchor in a seaway. *Titanic*'s compressors were each fitted with a control wheel mounted on a worm gear shaft. This shaft was connected to a toothed wheel. When turned, the mechanism would compress the springs, releasing the tooth so as to allow the chain to pass unobstructed for weighing anchor.

Photos of *Titanic*'s compressor housings reveal an arched band connected to the top of the cast iron block. This ring was referred to as a 'jump bar'. Its purpose was to keep the chain in line if it jumped while weighing anchor. This bar was attached with side clips to accept a piece of rectangular steel stock that could be inserted as an extra safety lock on the chains. This bar can also be observed in fitting-out photos of *Britannic*'s forecastle.

Windlasses

There is frequently confusion between the terms 'windlass' and 'capstan'. A windlass is a device powered and designed to handle a chain cable, but was generally mounted horizontally on iron and steel ships. A capstan, which is generally mounted vertically, is an appliance which winds a rope around a barrel. With this said, *Titanic*'s windlasses were more properly termed 'cable capstans', although 'windlass' is used here in deference to the original Harland & Wolff terminology. The

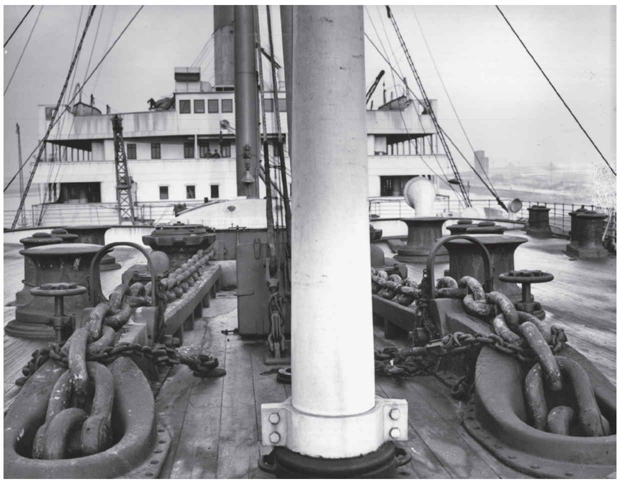


Fig. 20-21 **Chain Races and Stoppers** – Looking aft from *Olympic*'s prow during her 1912-13 refit. The chain races are in clear view, and the slip stoppers can be seen around the anchor cables by the mouths of the hawse pipes. Directly in the center foreground is the white-painted base of the anchor crane. *(H&W/Authors' collection)*

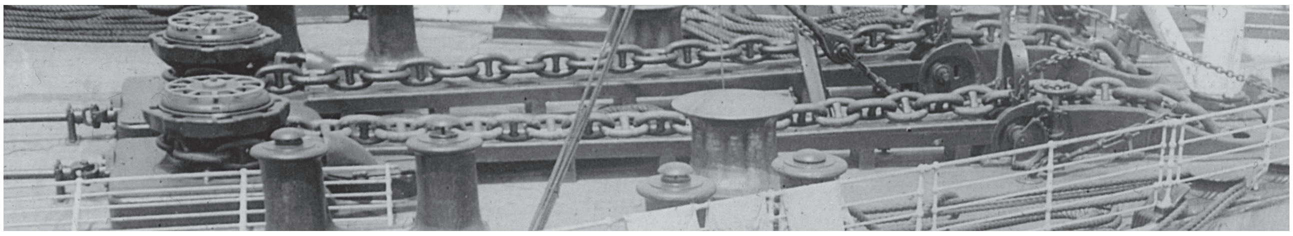


Fig. 20-22 **Chain Races and Windlasses** – An outstanding view of *Olympic*'s windlasses, showing the full length of the chain races with the anchor cables. *(Peter Davies-Garner collection)*

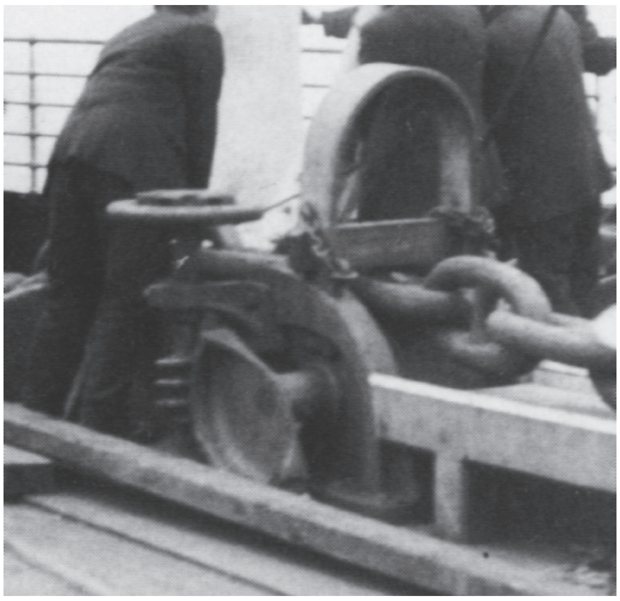


Fig. 20-23 **Compressor** – The port-side compressor on *Britannic*. These were the same on the three *Olympic*-class ships, and their design was said to be far stronger and more efficient then the old-style compressor which needed a physical lever to operate, such as that seen on the *Oceanic* and other smaller vessels. Also seen here is the steel bar piece which extended under the jump loop that added extra protection against chain slippage.

windlasses were steam-driven, each powered by its own engine located on the Shelter Deck (C) below.

The windlass equipment on *Titanic* was manufactured by Napier Brothers Ltd of Glasgow. The windlasses consisted of two cast-steel drums called 'cable wheels' around which the cables passed; each cable wheel had a deep groove in which projecting 'whelps' engaged with the links of the cable. The use of stud-link chain ensured that the cable would properly feed around the cable wheel and ensured that each whelp would properly engage its corresponding link. Each cable wheel was mounted upon a vertical spindle which was carried down to the Shelter Deck (C). The cable wheels turned loosely on the spindle but could be rigidly engaged with it by a clutch. Engaging the clutch caused the cable wheel to turn with the spindle, as would be done when heaving in the cable. When the clutch was disengaged, the cable wheel revolved freely, allowing the cable to run out[6] or pay out under the control of the brass-lined friction brake fitted to and beneath each cable wheel. These powerful brakes could be tightened to hold the cable wheel rigidly without moving or applied with just enough pressure to allow the cables to pay out at any desired speed. The brakes would also be tightened when riding by the brake.[7] The windlass brake control wheels and gears were located at a safe distance from the cable wheels, just forward of the No.1 Hatch. The gearboxes were connected to the windlass brakes through shafts equipped with universal joints extending forward along the deck.

The lower end of each spindle was keyed to a bevel gear of large diameter, driven at a ratio of 60-to-1 from one of the vertical windlass engines situated below the Forecastle Deck. Power to the windlasses was provided by two steam engines, each having two cylinders of 18in diameter and a 14in stroke. The drum for the wire rope anchor cable located at the prow of the ship on the Shelter Deck (C), as previously noted, was also powered by one of the windlass engines at ratio of 120-to-1. On the Shelter Deck there was also a single, centerline-mounted warping capstan directly powered by one of the windlass engines.

The manufacture of the windlass gear was extra-strong. All of the spur gears were of cast steel with machine-cut teeth. All bearings were gunmetal, adjustable, and had efficient and up-to-date lubricating arrangements for the time. The windlass spindles were made of the best forged mild steel, and were cut to the exact lengths from measurements made right off the ship after the decks were already fixed. The shafting of the machinery was of forged mild steel, and the clutches of cast steel. The cylinders were lagged with magnesia slabs 2in thick bedded in magnesia plastic and covered with planished sheet steel. All of the windlass parts were suitable for a working pressure of 100lb per square inch. The control gear of each engine, in addition to having a hand wheel at the engine, was also led by shafting and brass bevel gears to the Forecastle Deck above the gear, where there was fitted a portable brass pedestal and wheel for the on-deck control of each engine.

Capstans

Also manufactured by Napier Brothers, *Titanic* was equipped with numerous cast-steel capstans for warping[8]

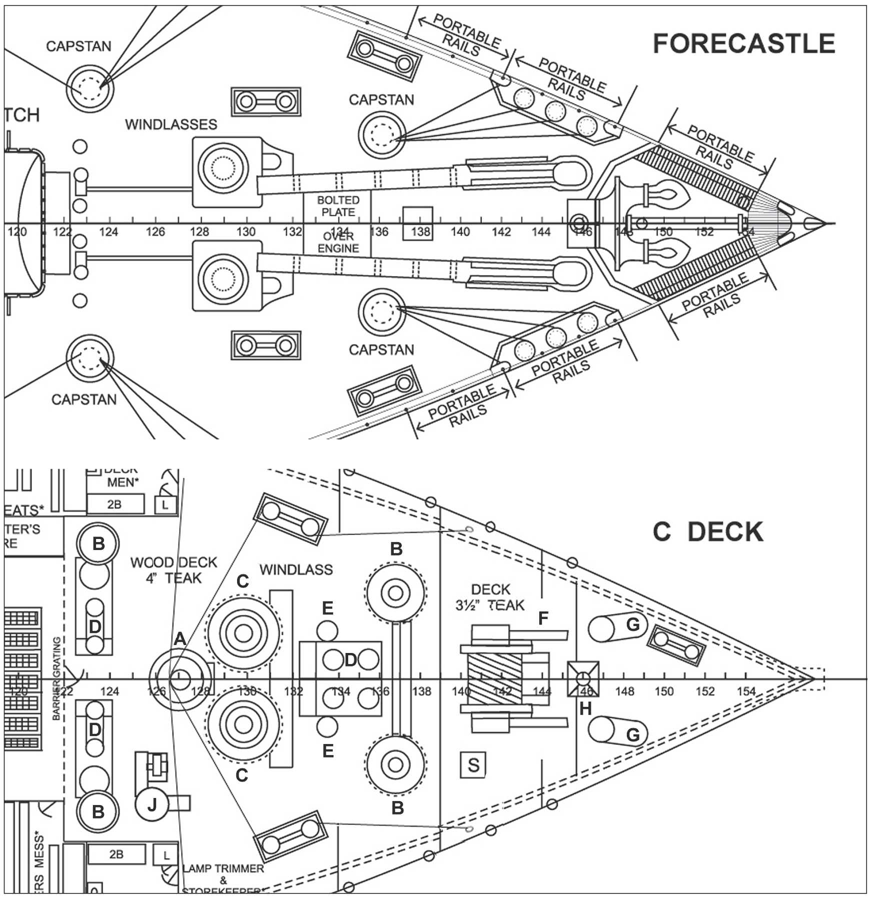


Fig. 20-24 **Windlass Illustration Plan** – This plan shows, in General Arrangement format, *Titanic*'s Forecastle Deck and the machinery on C Deck below. A – Capstan integrated into machinery at C Deck level; B – Spur wheels for capstans above on Forecastle Deck. C – Spur wheels for windlasses. D – Steam engines. E – Chain pipes to chain locker. F – Wire rope drum for center anchor, powered off of windlass engines. G – Hawse pipes. H – Step (mount) for center anchor davit above. J – Thermotank used for heating air for ventilation system, not part of the windlass installation. S – Scuttle to access store space in the deck below. *(Illustration by Bruce Beveridge)*

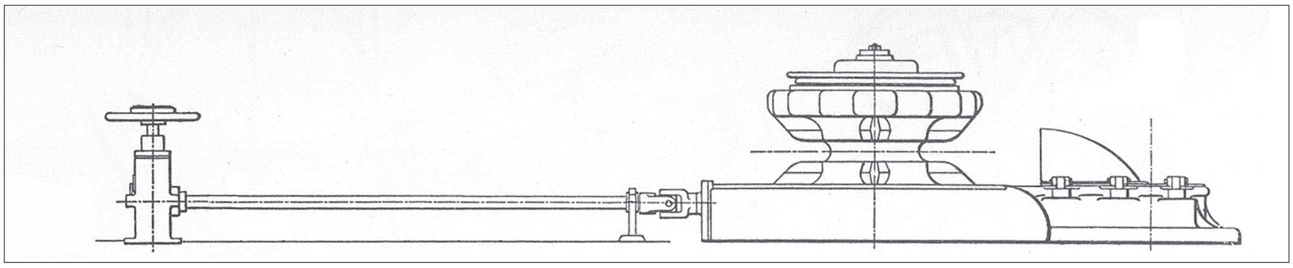


Fig. 20-25 **Napier Windlasses** –Napier windlasses and capstans were widely used by shipbuilders throughout the world in *Titanic*'s era. The *Aquitania* had nearly the same outfit as *Titanic*, as did the *Lusitania* and *Mauretania*. Harland & Wolff used Napier's products extensively; one particularly notable installation was the equipment supplied for the White Star Line's *Oceanic* (1899), illustration of which are used frequently in this chapter.

the ship in harbor. The forward warping gear consisted of four capstans located on the Forecastle Deck and one beneath on the Shelter Deck (C) for handling smaller ropes as is detailed above. The two foremost capstan spindles on the Forecastle Deck were driven by bevel gearing in a similar manner to that adopted in the case of the windlass drums, and powered by the same engines. A series of gears and clutches disengaged the windlasses in order to operate the capstans and vice versa. The capstan on the Shelter Deck was also powered by the windlass engines as stated above; this was geared at a ratio of 6-to-1.

The two after capstans on the Forecastle Deck were driven independently by separate engines located on the Shelter Deck below, each engine having two cylinders of 18in diameter and a 14in stroke suitable for working at a steam pressure of 100psi with a gear ratio for the capstans of 10-to-1.

On the Forecastle Deck, located just forward of the No.1 Hatch, were two portable brass pedestals with hand wheels to control these independent capstans. Two other hand wheels actuated the windlass/warping capstan engines as described previously; the additional two operated the throttles of the engines on the deck beneath.

Aft, four capstans were mounted on the Poop Deck with a fifth mounted below on the Shelter Deck (C).[9] On the Shelter Deck were four steam engines to provide power

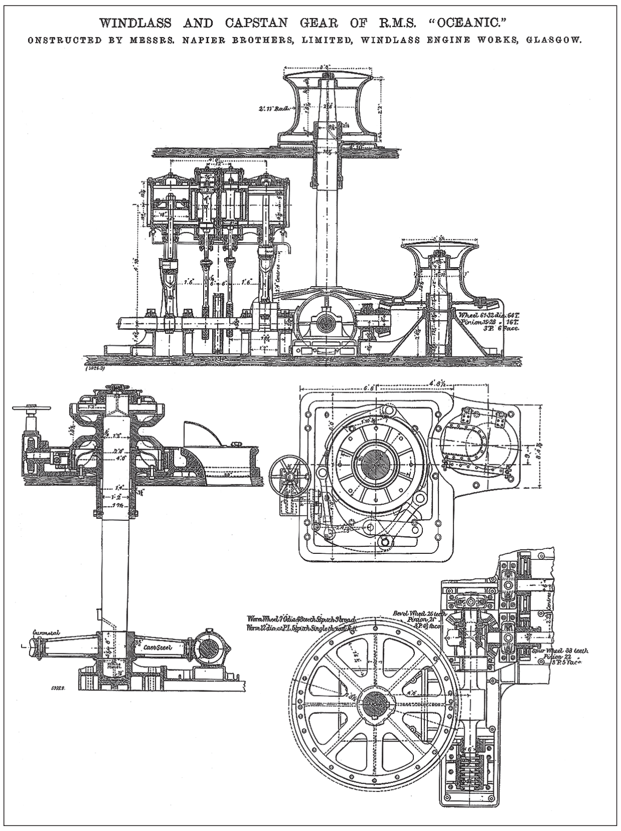

WINDLASS AND CAPSTAN GEAR OF R.M.S. "OCEANIC."
ONSTRUCTED BY MESSRS. NAPIER BROTHERS, LIMITED, WINDLASS ENGINE WORKS, GLASGOW.

Fig. 20-26 **Napier Windlass Equipment on *Oceanic*** – Details of *Oceanic*'s windlass equipment. A view of the brake mechanism complete with control wheel can be seen in the center of this illustration. *Titanic*'s control wheels were of the same design, but were located further aft so the crewmen releasing the windlass brakes would be well clear of the cable wheels when the anchors were let go. *(*Engineering*/Authors' collection)*

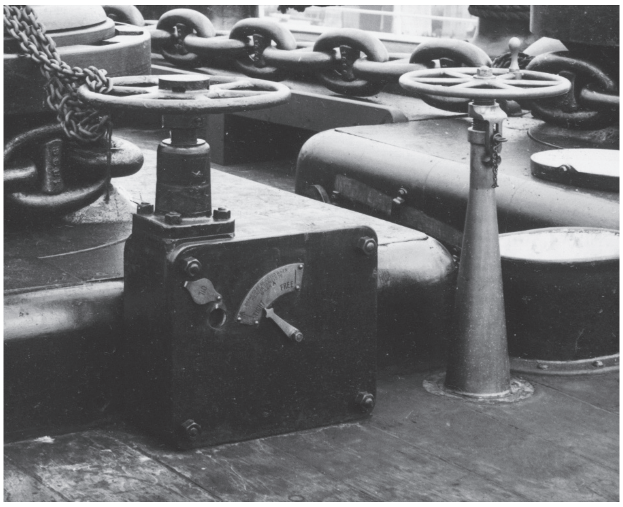


Fig. 20-27 **Control Pedestal and Windlass Brake on *Oceanic*** – In this image from *Oceanic* can be seen a Napier windlass brake wheel to the left and a capstan control pedestal to the right. These were the same as those fitted to *Titanic*. It should be noted that these brass steam control pedestals were portable, which may explain their absence on the wreck today.

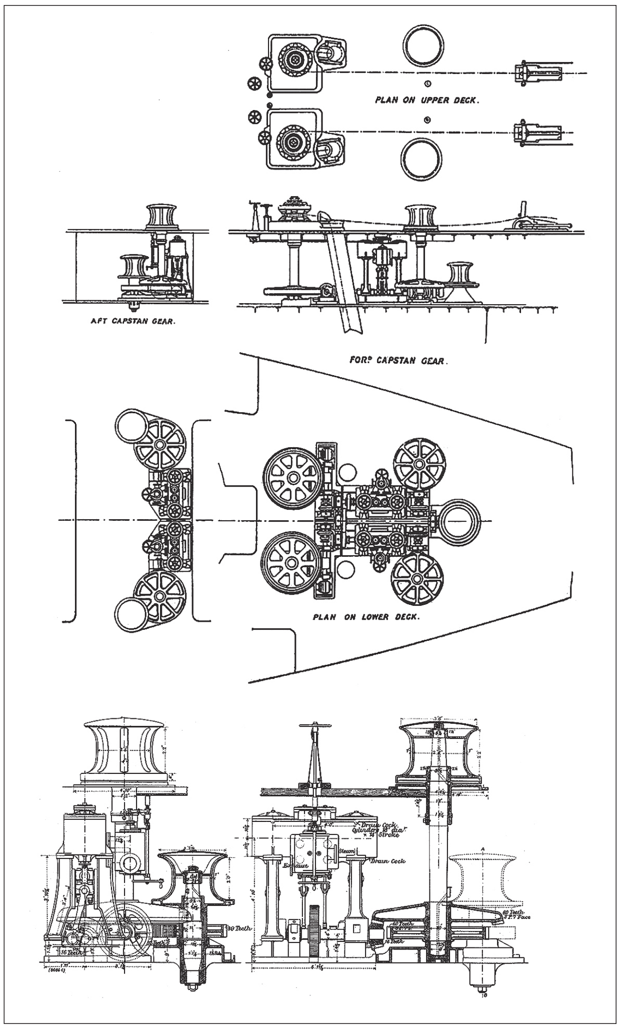


Fig. 20-28 **Napier Windlass Equipment on *Oceanic* – Plan and Profile View** – *Oceanic*'s windlass and capstan machinery, showing plan and profile views of the Forecastle Deck and the space below, as well as a detail of the capstan machinery with the steam engine and below-deck capstan similar to that aboard *Titanic*. *(*Engineering*/Authors' collection)*

to these drums, each engine having two cylinders of 18in diameter and a 14in stroke. The bearings, steps, etc., were of gunmetal, with the engine cylinders lagged to the same specifications as the windlass engines. One of the engines below the Poop Deck powered both a topside drum and a Shelter Deck drum. The gear ratio for the capstan drums on the Poop Deck was 10-to-1 and that at the Shelter Deck level was geared to a ratio of 4-to-1. As with the capstans forward, there were four portable pedestal-mounted hand wheels to control the speed of the capstans with hand wheels that turned in the same direction as the capstan to eliminate confusion. Two of these were located below the Docking Bridge on the deck, with the other two situated approximately 20ft abaft the first pair, each having an alternative control at the engine.

The capstan and capstan gear sole plates were of cast steel, the engine sole plates of cast iron. The capstan spindles were, as with the windlasses, made of the best forged mild steel and cut to length at the Napier Brothers works from measurements taken from the ship when the decks were fitted.

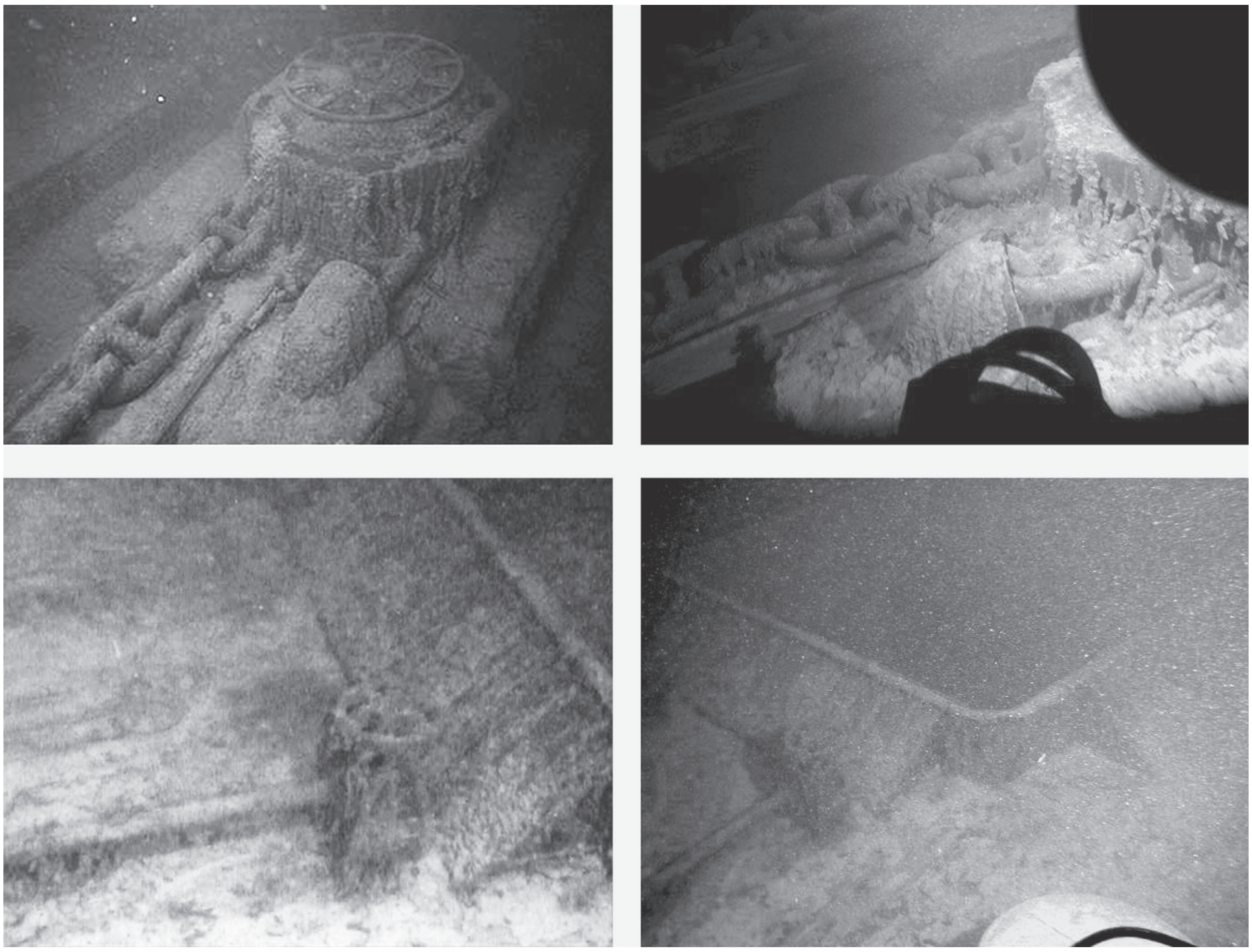


Fig. 20-29 **Image of Windlasses on Wreck** – Images from *Titanic*'s wreck, showing the windlasses and the shaft connected to the brake box and control wheel. *(Steve Rigby collection)*

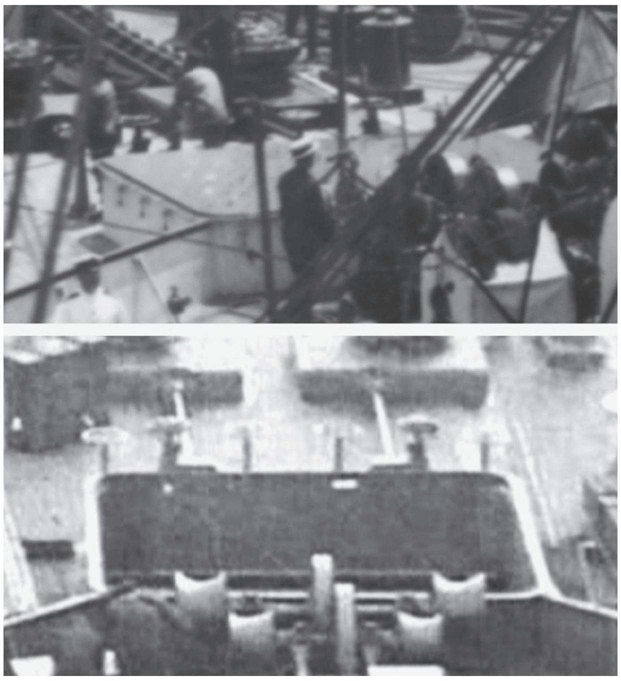


Fig. 20-30 **Capstan Pedestals on Forecastle** – As seen in this image of *Olympic*'s Forecastle Deck, there were four elevated wheels forward of the No. 1 Hatch coaming. These operated the throttle valves of the engines located on the deck below which drove the capstans and windlasses.

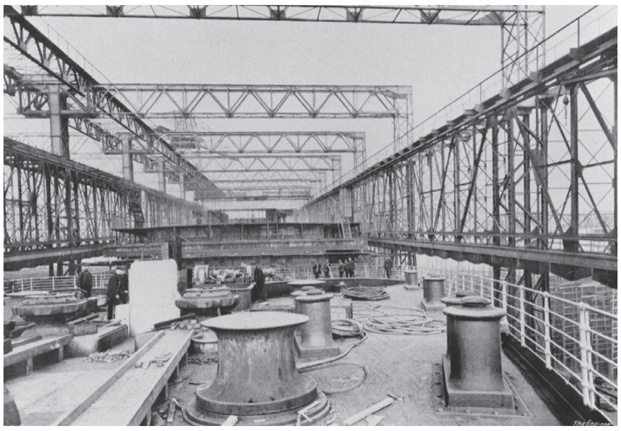


Fig. 20-31 ***Olympic*'s Forecastle Deck Under Construction** – The windlasses, chain races, a capstan and bitts can be seen here. Also visible here is a chequered plate between the chain races that was mounted flush with the deck. This plate was the cover over the windlass engines below on C Deck. On *Titanic*, this plate was fitted with two longitudinal channel bars, one on each side, presumably for added strength and to take bolts making it possible to disassemble the plate into pieces to access the engines below. In contrast, the plate fitted over *Olympic*'s windlass engines does not appear to have any seams. *(*The Engineer/*Authors' collection)*

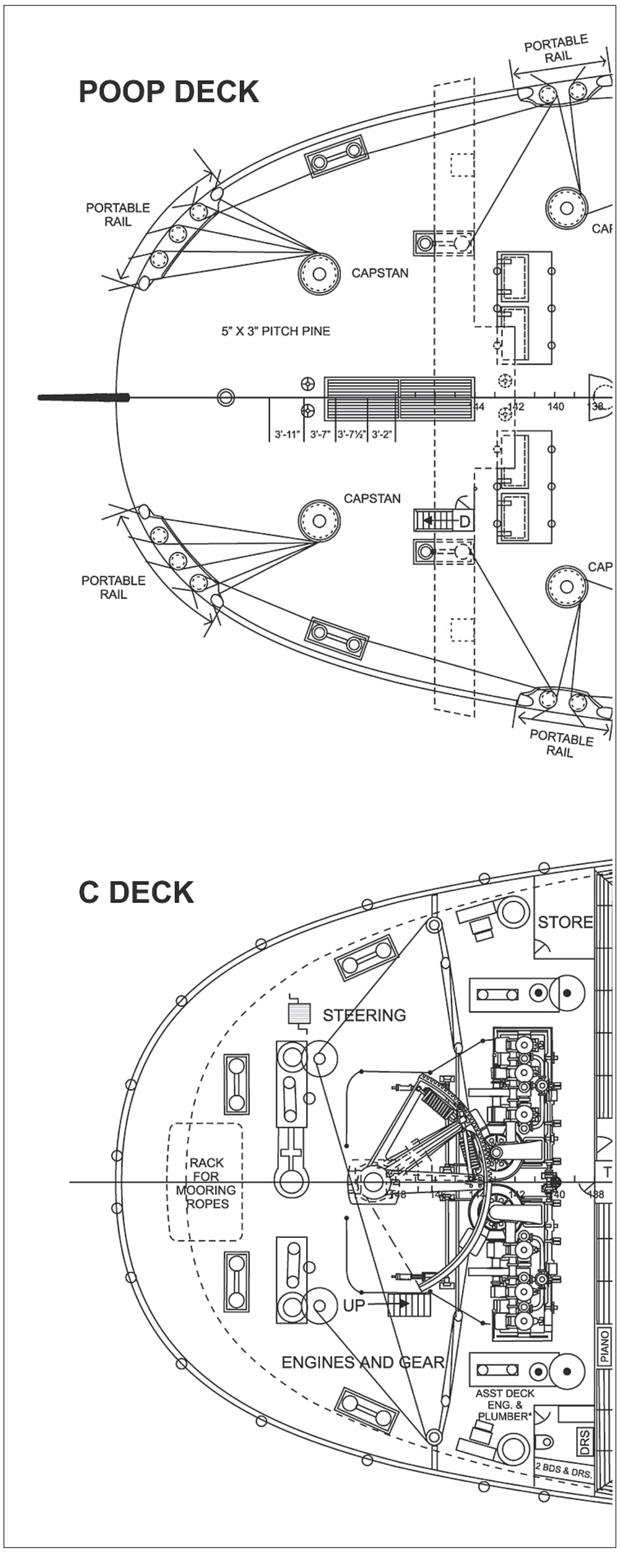

POOP DECK
PORTABLE RAIL
PORTABLE RAIL
CAPSTAN
CAP
5" X 3" PITCH PINE
144
142
140
138
3'-11"
3'-7"
3'-7½"
3'-2"
CAPSTAN
D
CAP
PORTABLE RAIL
PORTABLE RAIL
C DECK
STORE
STEERING
RACK FOR MOORING ROPES
148
140
138
T
UP
ENGINES AND GEAR
PIANO
ASST DECK ENG. & PLUMBER*
DRS
2 BDS & DRS.

Fig. 20-32 **Capstans Aft** – The capstan machinery on *Titanic*'s Poop Deck and C Deck levels. *(Illustrations by Bruce Beveridge)*

Mooring bitts

A large number of mooring bitts were provided on the ship for securing hawsers and warps. These were made of heavy cast steel and, in some cases, were designed to use their internal shafts for ventilation purposes to the deck space below. All bitts, whether or not they functioned as ventilating bitts, were hollow internally and molded on a rectangular base in order to raise the bitt castings above the level of the wood decking. This footing rested directly on the steel deck plates and was bolted rather then riveted in place. (The same type of footing was used for the capstan drums.) The diameters of the bitts were generally 18 or 21in at the tops of the posts below the stop cap. Two 21in bitts were placed between the capstans on the Forecastle Deck and were specifically intended for towing; an additional bitt was placed on the Shelter Deck (C) forward and to port of the center anchor windlass for use in towing, mooring or anchoring. All of the bitts located on the Poop and Forecastle Decks were of the ventilating type; the bitts located in the two Well Decks were not.

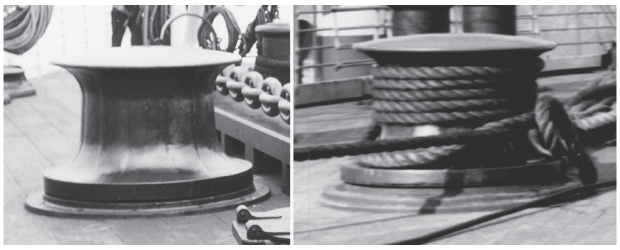


Fig. 20-33 **Capstan on *Oceanic*** – At left, one of *Oceanic*'s capstans on her Forecastle Deck. This capstan was the same size and design as *Titanic*'s. At right, a capstan in use on *Olympic*'s Poop Deck.

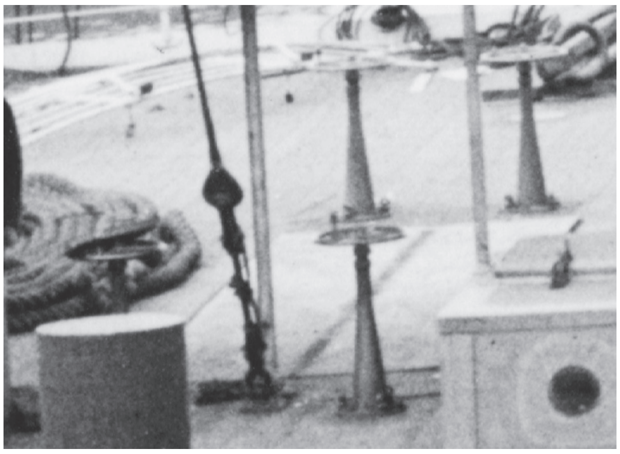


Fig. 20-34 **Capstan Control Pedestals on Poop Deck** – The steam control pedestals on *Olympic*'s Poop Deck. These were used for operating the four capstans. Visible at deck level between each pair of pedestals are the flush-fitted portable chequered plates which covered the accessway for shipping and removing the steering gear and windlass engines.

While addressing this subject it is worth noting that the terms 'bitt' and 'bollard' are often confused with one another. While the names have come to be used interchangeably they are, in fact, two entirely different entities. Bitts are mounted on a ship, while bollards are always mounted on a dock.[10] The evolution of the term

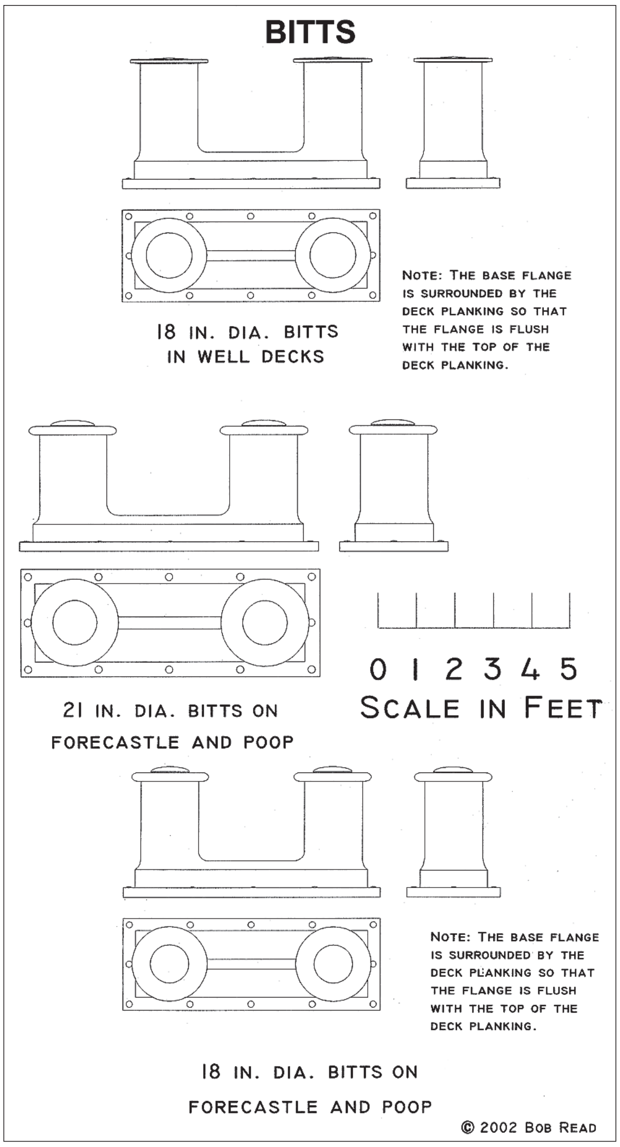

BITTS
Note: The base flange is surrounded by the deck planking so that the flange is flush with the top of the deck planking.
18 in. dia. bitts in well decks
0 1 2 3 4 5
Scale in Feet
21 in. dia. bitts on forecastle and poop
Note: The base flange is surrounded by the deck planking so that the flange is flush with the top of the deck planking.
18 in. dia. bitts on forecastle and poop
© 2002 Bob Read

Fig. 20-35 **Illustration of *Titanic*'s Bitts**. *(Illustration by Bob Read)*

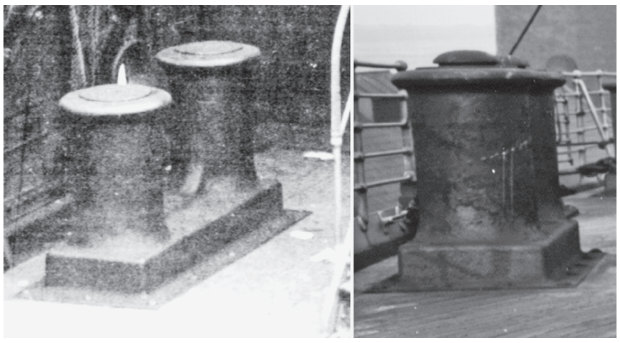


Fig. 20-36 **Bitts** – At left, a bitt in *Olympic*'s after Well Deck. The tops of the posts were fitted with flattened caps that were pressed into place over the hollow centers. Some of these caps are missing from the bitts seen in well decks on the wreck, giving the less-informed researcher the impression that they were of the ventilating type – but they were not. At right, a bitt from *Olympic*'s Forecastle Deck; this *is* of the ventilating type. The top of the post has the rounded mushroom type cap that readily identifies the ventilating bitts. More than likely, the caps missing from the posts of the well deck bitts were displaced as result of implosion during the wreck's descent to the ocean floor.

from a dock-based metal post to calling it a bollard aboard ship may have to do with the transition from wooden to iron ships (the original bitts on the tall ships were of wood).

Fairlead rollers

Fairlead rollers were fitted along the sides of the Forecastle and the Poop Decks to guide and direct the hawsers used for mooring and warping. A fairlead is a fitting at the outer edge of a deck, used to change the direction of a hawser so that it is delivered 'fairly' to the bitts or capstans for mooring or warping, respectively. In essence, it allows a line to come aboard at whatever point is most desirable before changing its direction toward a bitt or capstan with as little friction as possible.

The fairlead rollers were built of heavy cast steel with a curved chock molded on each side. The fairlead rollers were constructed with single, double, or treble rollers. The centers of the rollers were fitted with white-metal bearings that gave the appearance of a clover when viewed from the top. White metal was commonplace for bearings of this type, and the rollers had to be cleaned and lubricated regularly so as to avoid binding which would ruin the expensive mooring lines. The aft side of the stem head at the very forward tip of the bow was molded as a set of fairleads, and the bow pipe where the center anchor hawser was passed contained a roller casting to prevent chafing. Also considered part of the fairlead fitments were the low and elevated rollers located between the Nos 2 and 3 Hatches and Nos 5 and 6 Hatches; these are covered in the next chapter dealing with cargo handling equipment.

Warps and hawsers

Warps and hawsers were very large ropes used for towing and securing ships to piers and wharves. By the time of *Titanic*, hawsers of natural fiber had been almost totally replaced by wire hawsers, which were much stronger and longer-lasting.

Wire hawsers were used for towing, warping a ship around a dock and so forth and were required to be of great strength and flexibility. Wire rope hawsers were stowed on reels. These were Patent Purchase reels supplied by the Bullivant company and fitted with a pawl and ratchet, a hand crank, and a hand-operated band brake. Three were located on the weather decks; one on the Forecastle Deck forward of the mast and two on the Poop Deck at the forward edge of the deck near the port and starboard railings. The stowage of the

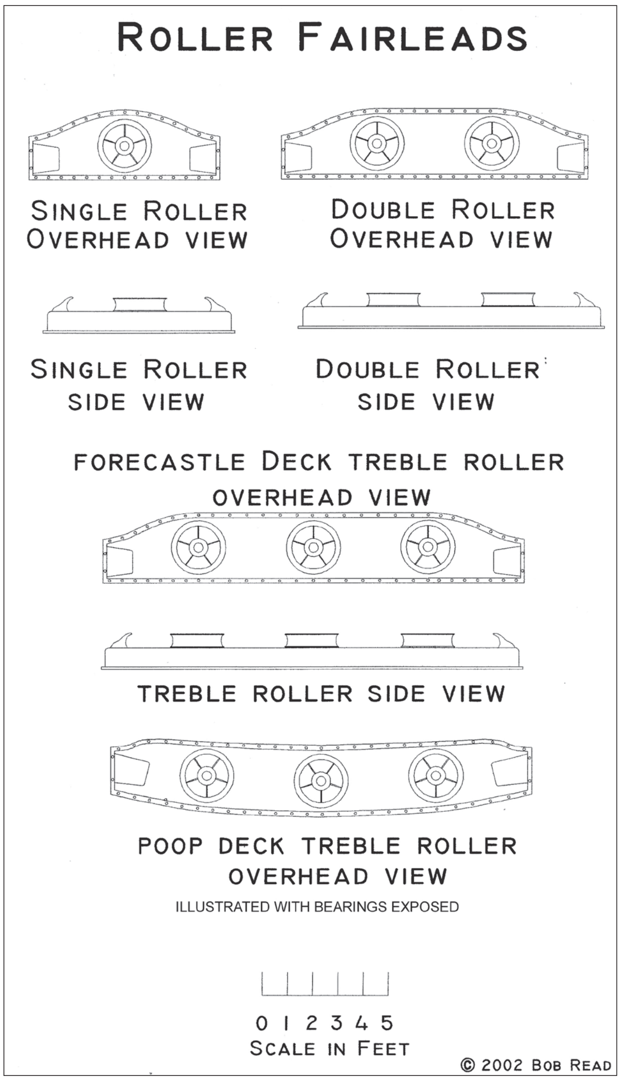

ROLLER FAIRLEADS
SINGLE ROLLER OVERHEAD VIEW
DOUBLE ROLLER OVERHEAD VIEW
SINGLE ROLLER SIDE VIEW
DOUBLE ROLLER SIDE VIEW
FORECASTLE DECK TREBLE ROLLER OVERHEAD VIEW
TREBLE ROLLER SIDE VIEW
POOP DECK TREBLE ROLLER OVERHEAD VIEW
ILLUSTRATED WITH BEARINGS EXPOSED
0 1 2 3 4 5
SCALE IN FEET
© 2002 BOB READ

Fig. 20-37 **Fairlead Roller Illustration.** *(Illustration by Bob Read)*

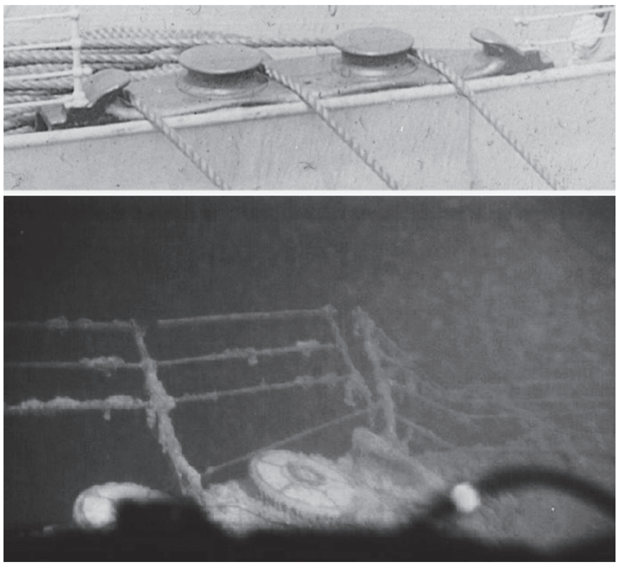


Fig. 20-38 **Fairleads on *Olympic*** – At top, one of *Olympic*'s fairleads on her starboard bow, and bottom, one of *Titanic*'s fairleads as it appears today with the white-metal bearings exposed. These fairleads stood approximately 15in high, and varied in shape and in number of leads depending on their placement on deck. *(Top image Peter Davies-Garner collection; bottom image Steve Rigby collection)*

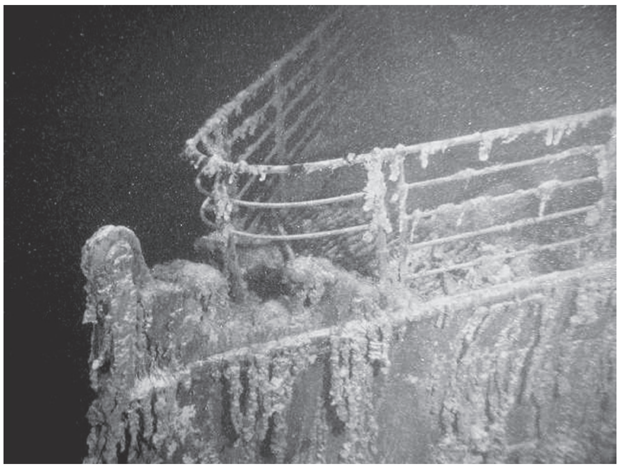


Fig. 20-39 **Fairleads on Prow** – This image from the *Titanic*'s wreck shows the large casting at the stem head which formed a fixed group of fairleads at the prow. Fairleads provided a surface for a wire rope or line to run across in order to change direction without chafing or kinking the material. The stem head still has part of the fitting for the mainmast forestays attached. Although this part of the ship was the location for one of the most famous scenes in James Cameron's film *Titanic*, in reality a passenger would never have been seen here because they were not allowed forward of the breakwater flanking the No.1 Hatch. *(Steve Rigby collection)*

wire hawser used for the center anchor and for towing has already been addressed in the anchor section.

Following are the technical specifications of some of the flexible steel wire hawsers and rope used on *Titanic*, the following being manufactured and supplied by Bullivant & Co:

Two 120-fathom, 7in-circumference galvanized flexible steel wire hawsers with galvanized thimble spliced in each end of each, on Patent Purchase Reels

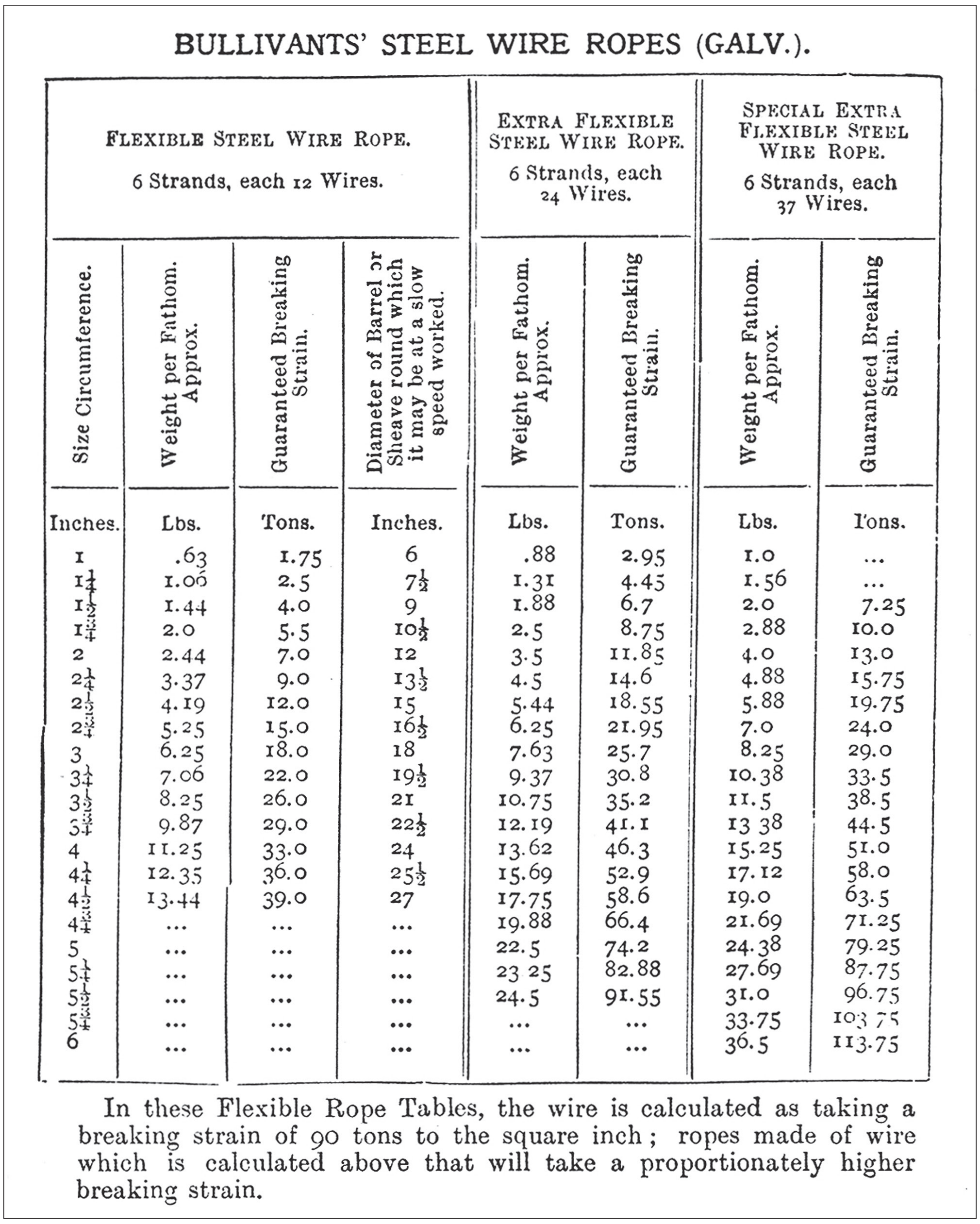
Two 100-fathom, 5in-circumference galvanized flexible steel wire hawsers with galvanized thimble spliced in each end of each, on Patent Purchase Reels

One 60-fathom, 4in-circumference galvanized flexible steel wire hawser on Patent Purchase reel, with 6ft 0in eye spliced in each end of the hawser for mooring the aft end of the ship through the breast pipe at New York

Ten 120-fathom, 8in-circumference Manila shroud-laid hawsers with 6ft 0in eye spliced in each end of each rope.

Six 30-fathom, 6in-circumference Manila shroud-laid hawsers, each with a Flemish Eye in one end and a 1ft 6in eye in the other end, for tenders when moored from the Bridge Deck (B).

Four 1in-diameter, 4ft 6in-long chain nippers and shackles for low moorings at Southampton



BULLIVANTS' STEEL WIRE ROPES (GALV.).

Flexible Steel Wire Rope. 6 Strands, each 12 Wires.				Extra Flexible Steel Wire Rope. 6 Strands, each 24 Wires.		Special Extra Flexible Steel Wire Rope. 6 Strands, each 37 Wires.	
Size Circumference.	Weight per Fathom. Approx.	Guaranteed Breaking Strain.	Diameter of Barrel or Sheave round which it may be at a slow speed worked.	Weight per Fathom. Approx.	Guaranteed Breaking Strain.	Weight per Fathom. Approx.	Guaranteed Breaking Strain.
Inches.	Lbs.	Tons.	Inches.	Lbs.	Tons.	Lbs.	I'ons.
1	.63	1.75	6	.88	2.95	1.0	...
1¼	1.06	2.5	7½	1.31	4.45	1.56	...
1½	1.44	4.0	9	1.88	6.7	2.0	7.25
1¾	2.0	5.5	10½	2.5	8.75	2.88	10.0
2	2.44	7.0	12	3.5	11.85	4.0	13.0
2¼	3.37	9.0	13½	4.5	14.6	4.88	15.75
2½	4.19	12.0	15	5.44	18.55	5.88	19.75
2¾	5.25	15.0	16½	6.25	21.95	7.0	24.0
3	6.25	18.0	18	7.63	25.7	8.25	29.0
3¼	7.06	22.0	19½	9.37	30.8	10.38	33.5
3½	8.25	26.0	21	10.75	35.2	11.5	38.5
3¾	9.87	29.0	22½	12.19	41.1	13 38	44.5
4	11.25	33.0	24	13.62	46.3	15.25	51.0
4¼	12.35	36.0	25½	15.69	52.9	17.12	58.0
4½	13.44	39.0	27	17.75	58.6	19.0	63.5
4¾	...	...	...	19.88	66.4	21.69	71.25
5	...	...	...	22.5	74.2	24.38	79.25
5¼	...	...	...	23 25	82.88	27.69	87.75
5½	...	...	...	24.5	91.55	31.0	96.75
5¾	...	...	...	...	...	33.75	103 75
6	...	...	...	...	...	36.5	113.75

In these Flexible Rope Tables, the wire is calculated as taking a breaking strain of 90 tons to the square inch; ropes made of wire which is calculated above that will take a proportionately higher breaking strain.

Fig. 20-40 **Bullivant Steel Wire Rope Table** – Shown here is a period steel wire rope table from the Bullivant company. In these flexible wire rope tables, the wire was calculated as taking a breaking strain of 90 tons to the square inch; ropes made of wire which were calculated above that would take a proportionately higher breaking strain.

Berthing

Titanic's size and displacement required the use of a large number of berthing hawsers when at the dock. Typically eighteen would be used, set up in specific positions to secure the ship against unwanted movement in all directions. 'Breast ropes' ran to the dock more or less perpendicular to the side of the ship, and checked outward movement. 'Springs' ran forward from the stern of the ship and aft from the bow of the ship at sharp angles; these prevented the ship surging forward or aft and assisted the breast ropes in keeping the ship in position. Additionally, if circumstances required, 'head ropes' leading well forward from the bow, and 'stern ropes' leading well aft from the stern, served in a similar manner to further limit fore-and-aft movement of the ship.

Mooring pipes

Where mooring lines could not be passed directly over the side of the ship (as they could on the Forecastle and Poop Decks), but had to pass through a bulwark or the side of the hull, 'mooring pipes' were provided. Four were located in each well deck, with others fitted in the shell plating below the Forecastle and Poop Decks. These permitted the mooring lines to pass easily through the steel plating of the hull. For mooring tenders to the ship, as at Queenstown and Cherbourg, mooring pipes were also located forward of the main First Class Entrance doors at D Deck for tenders. The access to these was hidden behind panels in the woodwork of the entrance foyers. Mooring pipes were made of cast steel, and in the case of the Well Decks, the thin bulwark plating was doubled in way of them, for if it yielded to the strain the pipe could fracture. The mooring pipes were positioned in all locations to give the mooring lines as straight a lead as possible to the large cast steel bitts bolted to the deck inboard of the mooring pipes.

Location of Mooring Pipes:
C Deck forward: two port and two starboard, fore and aft of ship's name at the bows
Forward Well Deck: two port and two starboard, at extreme fore and aft end of bulwark
After Well Deck: two port and two starboard, at extreme fore and aft end of bulwark
D Deck: one port and one starboard forward of First Class Entrance doors to First Class Reception Room
D Deck aft: four around stern in way of steering engine pace, two to each side of the ship

Mooring cleats

Titanic was fitted with 'mooring cleats' along the sides of the hull in certain locations. These devices were flush with the shell plating, and consisted of an oval-shaped recess in the hull plating, with a horizontal steel bar across the opening and around which mooring lines could be secured. These provided additional mooring points for tenders along the side of the hull. At G Deck level similar plates called 'eye plates' or 'low moorings' were provided but of larger diameter and with a vertical steel bar instead of a horizontal one.

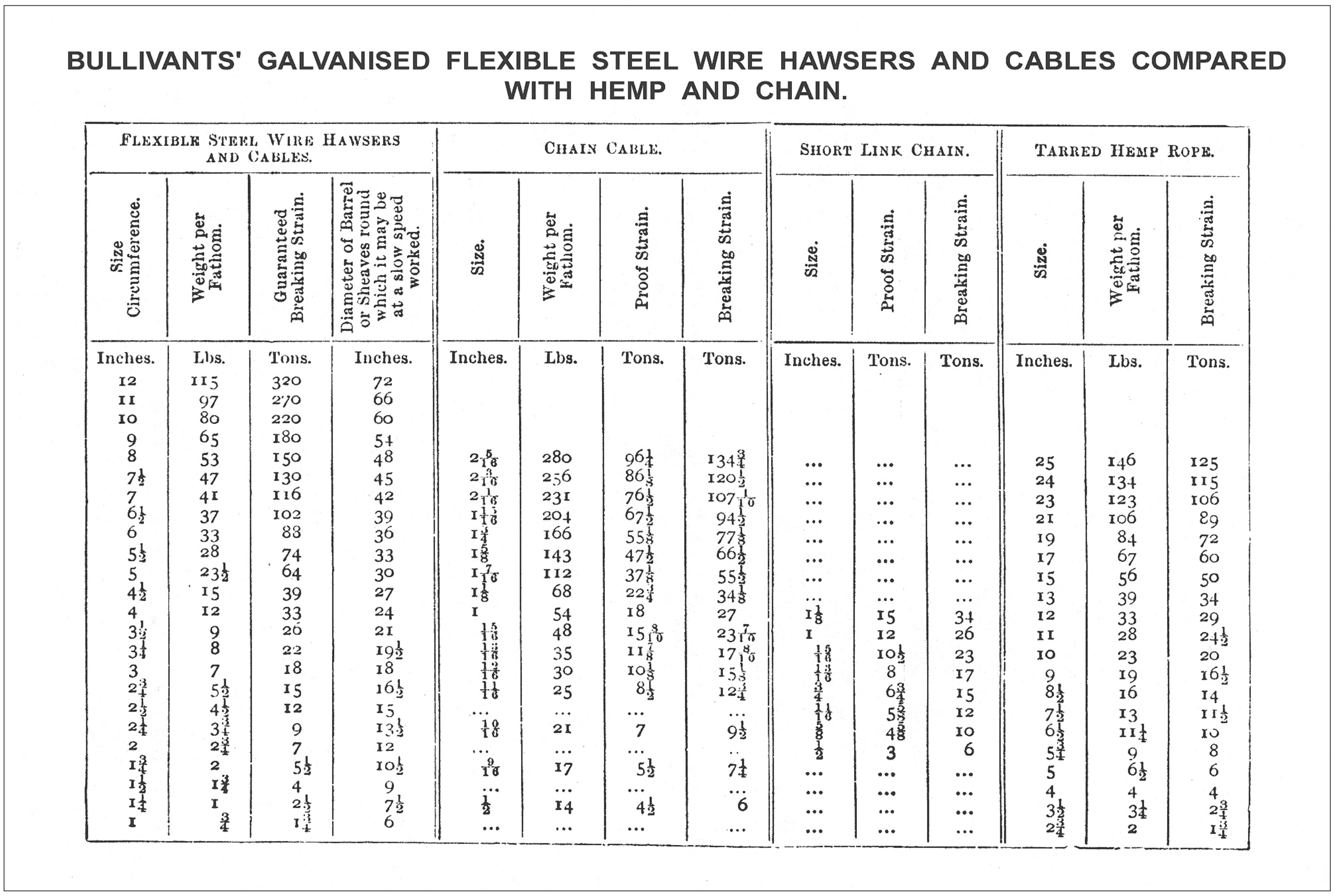
The locations of the mooring cleats and eye plates were as follows:

Mooring Cleats

Deck Level	**Side of Hull**	**Between Frames**
Between E and F Decks	Port & Starboard	118F & 119F
–	Port & Starboard	104F & 105F
Between E and D Decks	Port & Starboard	89F & 90F
–	Port & Starboard	71F & 72F
–	Port & Starboard	58F & 59F
–	Starboard	44F & 45F
–	Port	43F & 44F
–	Port & Starboard	25F & 26F
–	Port & Starboard	12F & 13F
–	Port	1F & 2F
–	Starboard	Midship
–	Port & Starboard	10A & 11A
–	Port & Starboard	24A & 25A
–	Port & Starboard	39A & 40A
–	Port & Starboard	34A & 35A
–	Port & Starboard	72A & 73A
–	Port & Starboard	95A & 96A
–	Port & Starboard	106A & 107A

Large Eye Plates or Low Moorings

Deck Level	**Side of Hull**	**Between Frames**
Between F and G Decks	Starboard	104F & 105F
–	Starboard	85F & 86F
Between E and F Decks	Port & Starboard	99A & 100A
–	Port & Starboard	115A & 116A



BULLIVANTS' GALVANISED FLEXIBLE STEEL WIRE HAWSERS AND CABLES COMPARED WITH HEMP AND CHAIN.

Flexible Steel Wire Hawsers and Cables				Chain Cable.				Short Link Chain.			Tarred Hemp Rope.		
Size Circumference.	Weight per Fathom.	Guaranteed Breaking Strain.	Diameter of Barrel or Sheaves round which it may be at a slow speed worked.	Size.	Weight per Fathom.	Proof Strain.	Breaking Strain.	Size.	Proof Strain.	Breaking Strain.	Size.	Weight per Fathom.	Breaking Strain.
Inches.	Lbs.	Tons.	Inches.	Inches.	Lbs.	Tons.	Tons.	Inches.	Tons.	Tons.	Inches.	Lbs.	Tons.
12	115	320	72										
11	97	270	66										
10	80	220	60										
9	65	180	54										
8	53	150	48	2 5/16	280	96¼	134¾	...	...	...	25	146	125
7½	47	130	45	2 3/16	256	86⅓	120½	...	...	...	24	134	115
7	41	116	42	2 1/16	231	76⅓	107 1/10	...	...	...	23	123	106
6½	37	102	39	1 13/16	204	67½	94½	...	...	...	21	106	89
6	33	88	36	1¾	166	55⅛	77⅛	...	...	...	19	84	72
5½	28	74	33	1⅝	143	47½	66½	...	...	...	17	67	60
5	23½	64	30	1 7/16	112	37⅛	55½	...	...	...	15	56	50
4½	15	39	27	1⅛	68	22¾	34⅛	...	...	...	13	39	34
4	12	33	24	1	54	18	27	1⅛	15	34	12	33	29
3½	9	26	21	15/16	48	15 8/10	23 7/10	1	12	26	11	28	24½
3¼	8	22	19½	13/16	35	11⅞	17 8/10	15/16	10½	23	10	23	20
3	7	18	18	12/16	30	10⅓	15⅓	13/16	8	17	9	19	16½
2¾	5½	15	16½	11/16	25	8½	12¾	¾	6¾	15	8½	16	14
2½	4½	12	15	...	...	...	...	11/16	5⅜	12	7½	13	11½
2¼	3¾	9	13½	10/16	21	7	9½	⅝	4⅝	10	6⅓	11¼	10
2	2¾	7	12	...	...	...	..	½	3	6	5¾	9	8
1¾	2	5½	10½	9/16	17	5½	7¼	...	...	...	5	6½	6
1½	1¾	4	9	...	...	...	...	...	...	...	4	4	4
1¼	1	2½	7½	½	14	4½	6	...	...	...	3½	3¼	2¾
1	¾	1¾	6	...	...	...	...	...	...	...	2¾	2	1¾

Fig. 20-41 **Bullivant's Steel Wire Rope Comparison Table.**

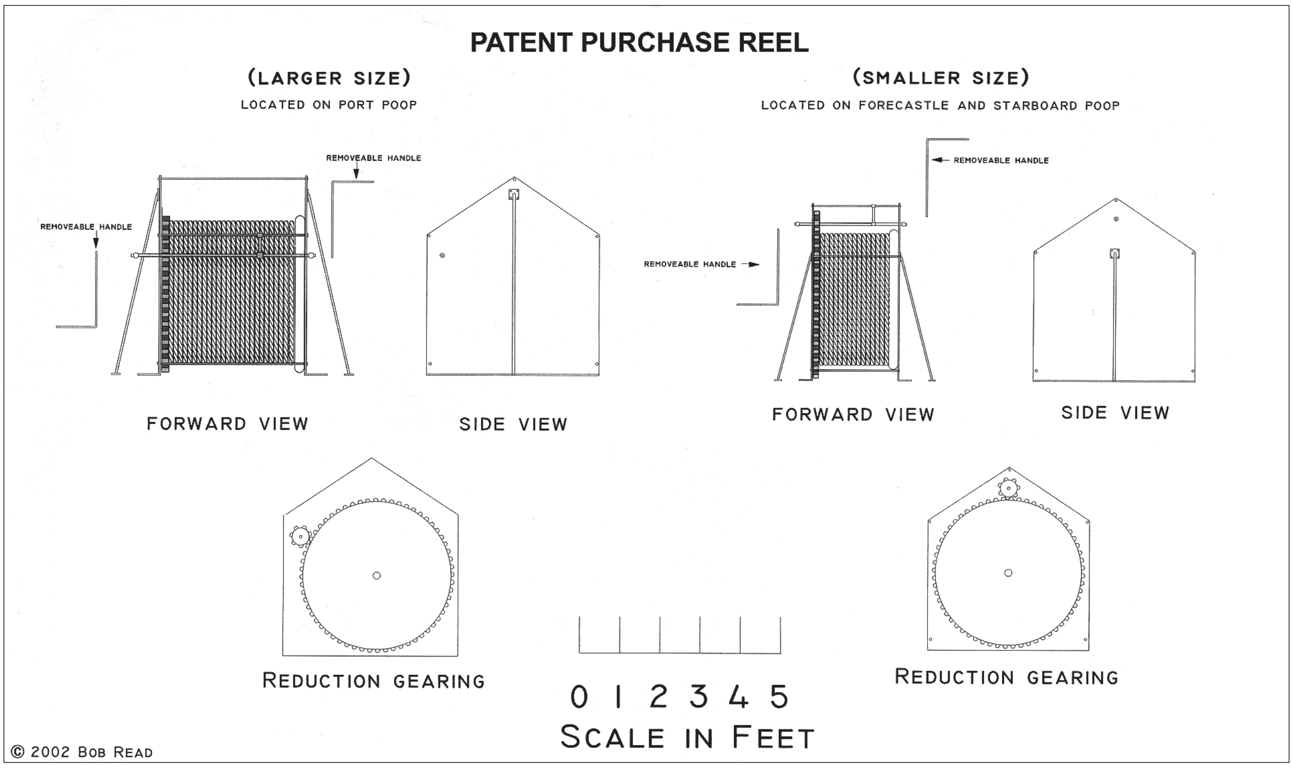
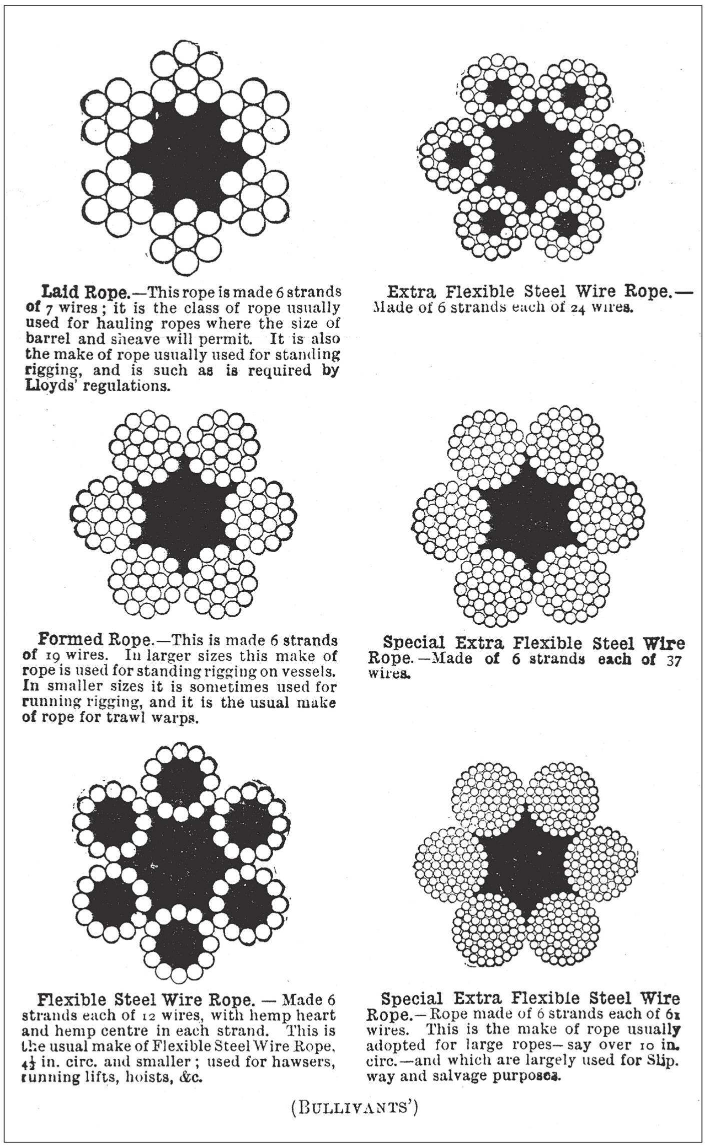

PATENT PURCHASE REEL
(LARGER SIZE)
LOCATED ON PORT POOP
REMOVEABLE HANDLE
REMOVEABLE HANDLE
FORWARD VIEW
SIDE VIEW
(SMALLER SIZE)
LOCATED ON FORECASTLE AND STARBOARD POOP
REMOVEABLE HANDLE
REMOVEABLE HANDLE
FORWARD VIEW
SIDE VIEW
REDUCTION GEARING
REDUCTION GEARING
0 1 2 3 4 5
SCALE IN FEET
© 2002 BOB READ

Fig. 20-42 **Patent Purchase Reel**. *(Illustration by Bob Read)*



Laid Rope.—This rope is made 6 strands of 7 wires; it is the class of rope usually used for hauling ropes where the size of barrel and sheave will permit. It is also the make of rope usually used for standing rigging, and is such as is required by Lloyds' regulations.

Extra Flexible Steel Wire Rope.—Made of 6 strands each of 24 wires.

Formed Rope.—This is made 6 strands of 19 wires. In larger sizes this make of rope is used for standing rigging on vessels. In smaller sizes it is sometimes used for running rigging, and it is the usual make of rope for trawl warps.

Special Extra Flexible Steel Wire Rope.—Made of 6 strands each of 37 wires.

Flexible Steel Wire Rope. — Made 6 strands each of 12 wires, with hemp heart and hemp centre in each strand. This is the usual make of Flexible Steel Wire Rope, 4½ in. circ. and smaller; used for hawsers, running lifts, hoists, &c.

Special Extra Flexible Steel Wire Rope.—Rope made of 6 strands each of 61 wires. This is the make of rope usually adopted for large ropes—say over 10 in. circ.—and which are largely used for Slip-way and salvage purposes.

(BULLIVANTS')

Fig. 20-43 **Various Makes of Wire Rope** – Wire rope, where flexibility was not necessary, was usually made of six strands of seven wires each, with the six strands laid over a single-strand core of softer wire. In many cases, however, the sheaves or winding drums were too small in diameter to allow such a braid of rope to be worked, in which case flexibility was obtained by increasing the number of wires in each strand.

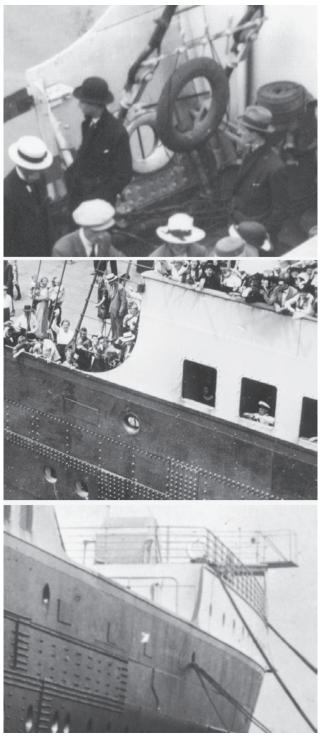


Fig. 20-44 **Mooring Pipes** – At top, a mooring pipe as seen from the forward Well Deck on *Olympic* in 1920. At center, *Olympic*'s mooring pipes in her after Well Deck as seen from the dock, and at bottom, one of *Olympic*'s after mooring pipes in use in 1912.

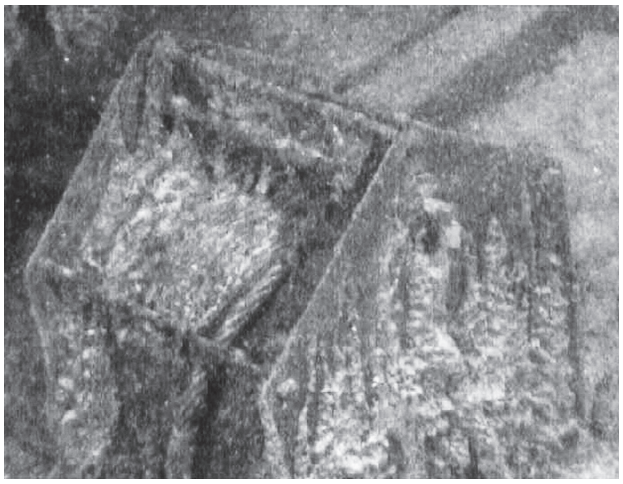


Fig. 20-45 **Wire Rope Reel on Wreck** – The wire rope reel on *Titanic*'s Forecastle Deck as it appears on the wreck today. *(Steve Rigby collection)*

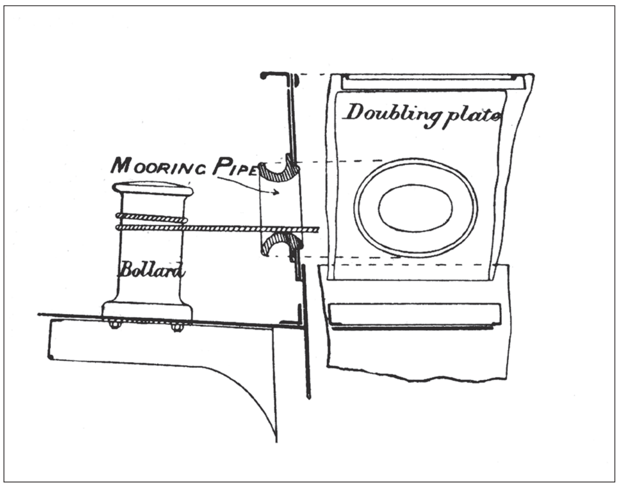


Fig. 20-46 **Illustration of Mooring Pipe and Bitt** – A mooring pipe and bitt as illustrated in a period technical reference on ship construction. Though this example of a mooring pipe is a bit different then *Titanic*'s, the way in which it was used in connection with the bitt is the same, and remains unchanged to the present day. A mooring pipe is nothing more than a smooth-mouthed hole that prevents chafing of the line. *(Illustration from* Practical Shipbuilding*)*

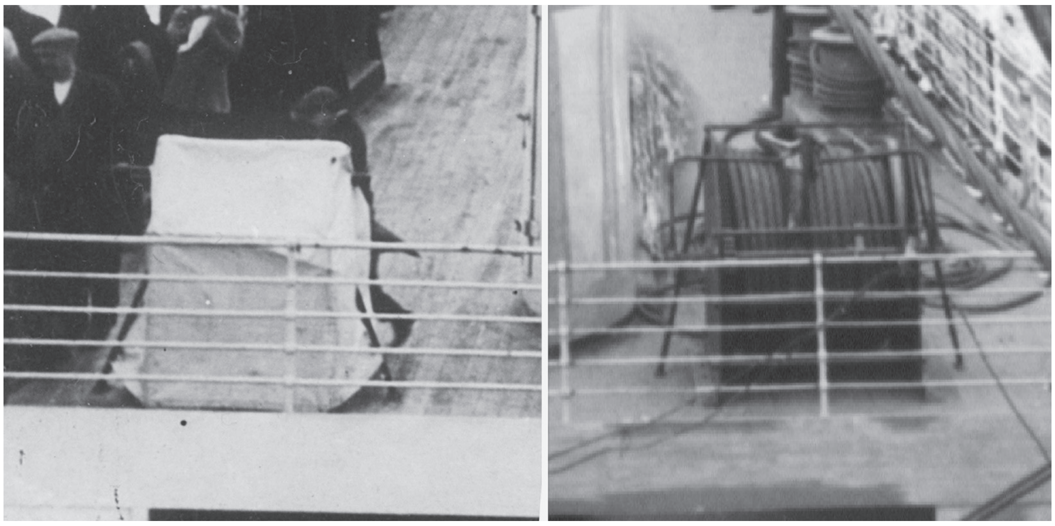


Fig. 20-47 **Wire Rope Reels on *Titanic* and *Olympic*** – At left, the wire rope reel on the forward end of *Titanic*'s Poop Deck, starboard side. At right, the smaller reel on the opposite side of *Olympic*'s Poop Deck. These were almost always photographed with their canvas cover in place; this rare view shows the reel uncovered. *(Both images authors' collection)*

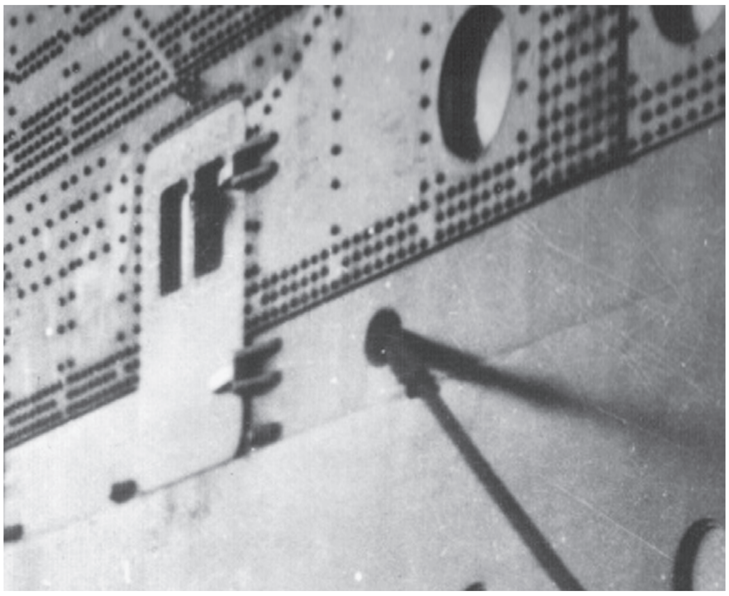


Fig. 20-48 **Mooring Pipe at D Deck Level** – The D Deck mooring pipe on *Titanic*'s starboard side, just forward of the main shell doors.

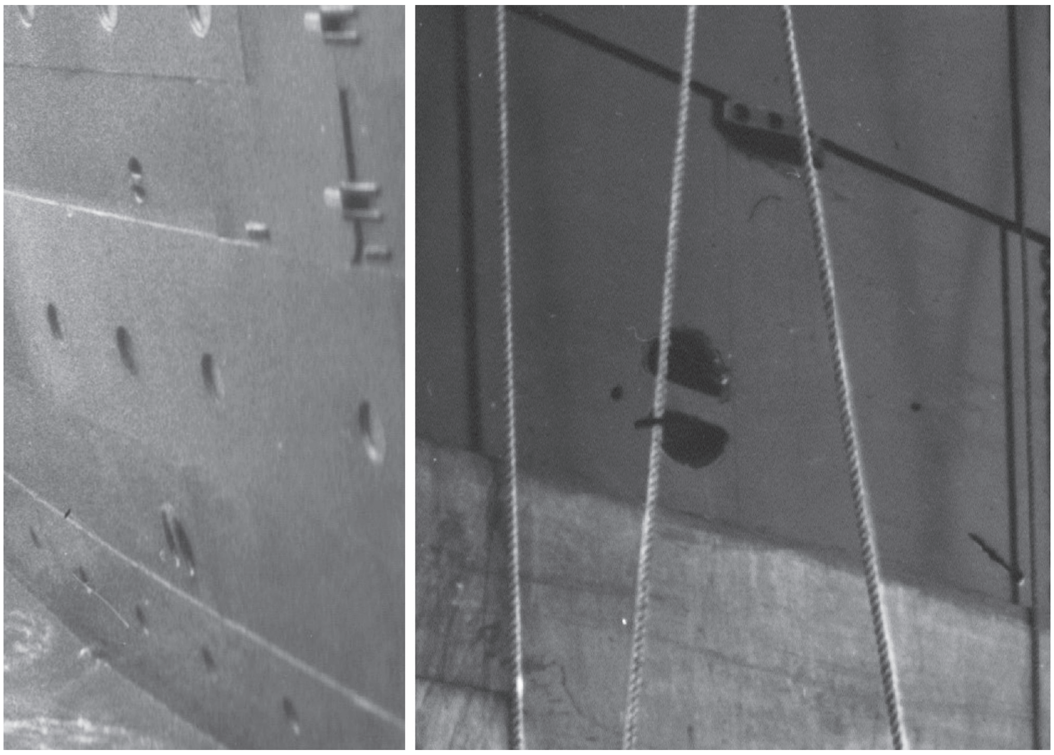


Fig. 20-49 **Mooring Cleats** – Examples of mooring cleats from *Olympic*. At left, a view of both types of mooring cleats. The bottom ones, commonly termed 'low moorings,' had vertical crossbars. The upper ones had horizontal crossbars. At right, a close-up of one of the upper cleats. The locations of all mooring cleats can be seen in the Rigging Plan that appears elsewhere in this book. *(Both images from authors' collection)*

Notes

1. When referring to measurements of weight on *Titanic*, it must be remembered that the unit of measurement was the British, or 'Long,' Ton which is 2,240lb. This is different from the common American, or 'Short,' Ton of 2,000lb or the metric Tonne equivalent to 2,204.62lb in use today. When calculating in Long Tons, a few terms must be clarified: 16 ounces is equal to one pound (lb), 28lb are equal to 1 quarter (qr), 4 quarters are equal to 1 long hundredweight (cwt) and 20 hundredweights are equal to 1 long ton (T) or 2,240lb.

2. Although Edwards described this as *Titanic*'s anchor, historical records and photograph evidence indicates that he could not have been speaking of *Titanic*'s anchor, but instead was recalling *Olympic*'s.

3. This anchor was occasionally referred to as 'stern anchor;' this is how it was listed in the BOT Survey documents.

4. The term 'weld' in this instance is describing the process of joining to pieces of metal that are red hot, and then fusing them together by hammering. It is not the same as electric or acetylene welding as is well-known today.

5. 'Cable wheel' is a British term and is synonymous with 'cable holder' or 'cable lifter;' the term 'wild cat' was generally used in the US Navy. 'Cable wheel' is the term used by Harland & Wolff and so has been used here.

6. 'Running out' the cable is similar to 'letting go' the anchor, except the anchor is already set.

7. 'Riding' refers to 'riding at anchor,' or maintaining the ship's position by having an anchor deployed. 'Riding by the brake' means that the entire strain from the anchor cable was borne by the windlass brakes, rather than the stoppers ('riding stoppers') that would normally be employed if the ship would be at anchor for any length of time. Harland & Wolff specified that the windlasses were to be strong enough to handle this strain.

8. 'Warping' is the process of moving a vessel about a harbor or dock without tugs, by securing the ship's hawsers to bitts and 'walking the ship along' by using the capstans to haul in on the hawsers.

9. This capstan was located in the same compartment as the steering engines, and could be rigged to the steering quadrant in an emergency to move the rudder should both steering engines be disabled.

10. In the earlier days of wood-hulled sailing vessels, ships were tied off to practically anything convenient. In response to the damage to ships which often resulted from this practice, Captain Frederick Bollard petitioned the Admiralty to install iron or wooden pillars at regular intervals along the docks. His idea was so successful that the Admiralty issued Captain Bollard a pension of £140 a year in recognition of the significant reduction in repair costs to its ships over a three-year period.

Chapter 21

Cranes, Winches and General Cargo-Handling Equipment

Titanic, like all transatlantic liners of her era, was designed to earn revenue from the carriage of cargo as well as passengers. In addition, every trip required provisioning the ship with stores (supplies, perishable and refrigerated foodstuffs), and loading the large amounts of baggage that came aboard with the passengers. As a Royal Mail steamer, the carriage of Royal and US Mail also comprised an important part of the cargo. The following table gives *Titanic*'s capacities for cargo, mail, baggage and stores.[1]

It is worth remembering that in 1912 palletized freight, containerized shipping and semi-automated loading systems did not exist, and a ship like *Titanic* had to load and accommodate many different types of cargo in widely differing configurations, quantities and types of packaging. Some examples from *Titanic*'s varied cargo manifest include a cask of china, bales of straw, boxes of melons, cases of furniture, a case of machinery, rolls of linoleum, barrels of mercury and a quantity of oak beams. Each cargo had its own unique considerations for loading and stowage, and all had to be accommodated together. Heavier weights were kept lower down in the holds, lighter stowage higher up. Cargo giving off odors was to be kept separate, and all cargo had to be protected from getting wet. Ventilation was important, and the weight was to be balanced and kept from shifting. In addition, *Titanic* was scheduled to call at several ports on each voyage, and each might require the offloading of some cargo. Cargo diagrams were often of great use when a vessel carried mixed stowage to be discharged at several ports, or when it became necessary to break out cargo for any reason. The diagram was generally a simplified fore-and-aft section of the ship, somewhat exaggerated as to depth. The officer in charge of the holds was to prepare this diagram himself. Where goods liable to pilferage were 'blocked off' by less tempting cargo, the diagram showed when and where to be extra careful while discharging. (A sharp lookout had to be kept for pilfering, especially with loose stowage not in sealed crates.)

In order to expeditiously load and unload the ship, *Titanic* was equipped with a variety of modern cargo-handling equipment, supplemented by specialized cargo rigging. While *Titanic* could load cargo and baggage directly from the dock into her holds, not all was loaded this way: some was transferred first to the forward or after Well Decks, and then into the holds.

Cargo Capacities by Hatch and Type of Cargo

Hatch Number	Type	Capacity
Forward:	–	–
1	General cargo	730 tons
2	General cargo & motorcars	1,341 tons
3	First and Second Class baggage	19,455 cubic ft
3	Mail, parcels and specie	268 tons
Aft:	–	–
4	Uninsulated stores	15,505 cubic ft
4	Insulated (refrigerated) stores	29,557 cubic ft
5	Insulated (refrigerated) cargo	390 tons
6	General cargo; Third Class baggage	366 tons
6	Potato stores (insulated)	1,420 cubic ft

Electric cranes

There were two 30cwt and six 50cwt[2] electric deck cranes fitted on *Titanic* for cargo handling. They were supplied by Stothert & Pitt Ltd of Bath, and were mounted on cylindrical bases containing the motors, worm gearing and operating machinery, each base fitted with two watertight doors. Because of their proximity to passenger accommodations, electric power and worm gearing was chosen for these cranes to reduce noise levels. Each crane was capable of lifting and slewing motions, powered by separate motors. All controls were located on an operator's platform at the base of the crane's mast. The platform for the operator was fitted with protecting handrails.

The two cranes in the forward Well Deck servicing the No.3 (Bunker) Hold had a radius of 27ft, a height from the deck to the center of the pulley of 29ft, and a total lift of 100ft. The two in the after Well Deck servicing the No.5 Hold had a radius of 28ft and a height from the deck to center of the pulley of 27ft. The cranes on the Poop Deck servicing the No.6 Hold had a radius of 29ft and a height from the deck to the center of the pulley of 26ft; their platforms were 11ft 8in in diameter and were about 6ft tall.

The two cranes in each of the above pairs were positioned 24ft apart center-to-center. Each of these cranes had a hoisting motor of 40BHP, a slewing (horizontal rotation) motor of 5BHP, a lifting speed at full load of 160ft per minute and a slewing speed of 500ft per minute at the hook. The lifting speed increased with lighter loads.

The smaller cranes were mounted at the after end of A Deck both port and starboard to service the hatches of the No.4 Hold, used for the loading of stores (primarily foodstuffs). These cranes had a radius of 21ft, a height from the deck to center of the pulley of 20ft and a total lift of 80ft. Their hoisting motors were rated at 30BHP and the slewing motors at 3BHP. The lifting speed at full load was 200ft per minute and the slewing speed was 500ft per minute at the hook.

The lifting gear, which was arranged on Stothert & Pitt's free-barrel system with its patented interlocks between coil clutch, brake, and controller, was driven by single-reduction worm gear. The slewing motion was also operated by worm gearing, driving a pinion engaging with the slewing ring attached to the bedplate. A mechanical brake was fitted and was interlocked with the controller to prevent current being applied when the brake was on. When slewing, the superstructure revolved on a live ring of steel rollers between the top and bottom paths of steel. The horizontal thrust was taken by rollers bearing on a path turned on the post. All the gearing had machine-cut teeth, and the worm gears revolved in oil-bath gear cases with glands to prevent leakage of oil. The worms were case-hardened and ground true; worm shafts were fitted with ball thrust bearings, and worm wheels had phosphor-bronze toothed rings. Inside the base, the post around which the crane revolved was secured to a massive casting bolted to the deck; this casting also carried the curb ring and bottom roller path. The motors, supplied by Laurence, Scott & Co. Ltd, were totally enclosed and were series wound for electric current at 100 volts. A controller with resistances was fitted to each motor, the controllers being of the enclosed type for protection from the weather.

The crane jibs consisted of steel plate-and-angle construction of box section, each fitted with a ball-bearing swiveling cargo hook at the end. When the crane was in use, a support cable was attached to the top of the mast on each side, running around a horizontal sheave connected to a bracket at the end of the jib. This design, utilizing a single cable passing around a sheave instead of two separate cables, ensured equal tension on each both sides of the jib. Appearance to the contrary, the crane jibs were fixed in position when use. Each crane was readied for use by using the hoist cable to raise the jib to the proper angle; the support cable was then attached on each side, and the hoist cable slackened to tension the support cables.

At the top of the mast, internally mounted, was a barrel grooved to suit the wire hoist rope. The barrel was provided with a powerful foot brake, also an auxiliary brake that could be instantaneously applied by the driver in case of emergency. The base of the mast was attached to a circular girder forming the top roller-path and carried the operator's platform.

When the cranes were not in use, the support cables were detached and the jibs were lowered to the horizontal level, resting on top of supports or 'crutches' bolted to the deck. The cranes on the Poop Deck shared the same crutches (two in number) as did the two cranes on the forward Well Deck, which shared three crutches. In each case, the crutches stood between the cranes: the jib of one crane rested on the crutches, and the jib of the second crane rested on top of the other crane's jib. The cranes at the after end of A Deck and in the after Well Deck each had their own individual (single) crutches. All crane jibs were clamped to their crutches by means of a steel plate on top, secured on either side by a threaded rod and nut.

Derrick

Titanic was equipped with a Mannesmann steel tubular mast derrick located on the after side of the foremast to assist with loading cargo into the forward Well Deck and associated hatches. This derrick was essentially a simple

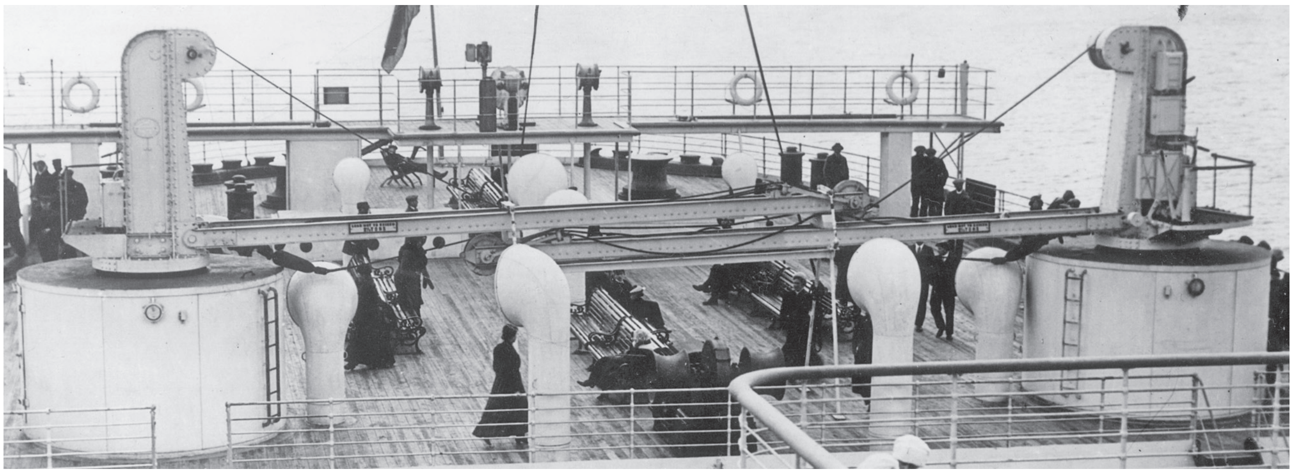


Fig. 21-1 Cranes on Poop Deck, *Titanic* – The 50cwt cranes on *Titanic*'s Poop Deck, with the jibs resting on their crutches.

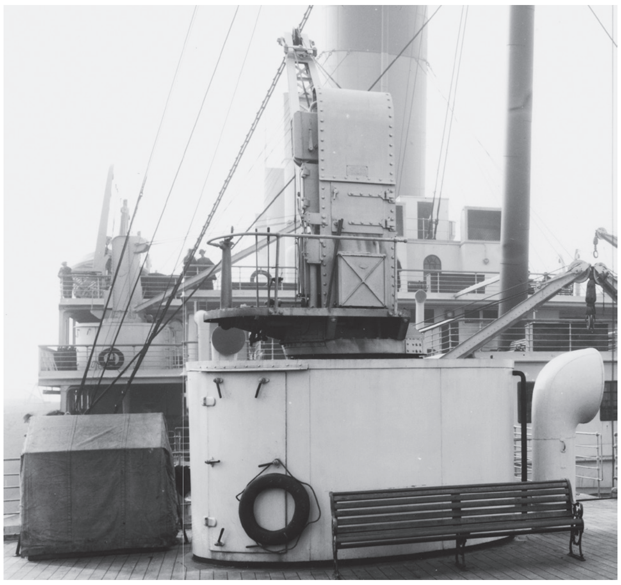


Fig. 21-2 **View of Poop Deck Cranes Looking Forward** – A view from later in *Olympic*'s career, looking forward on her Poop Deck. The structure of these cranes remained unchanged throughout the life of the ship, and for that reason this rare view is of particular value because it shows, in great detail, the after side of these cranes. One of the A Deck cranes is also visible in the distance. The canvas-covered object at the left of the photograph is a wire rope reel. *(Daniel Klistorner collection)*

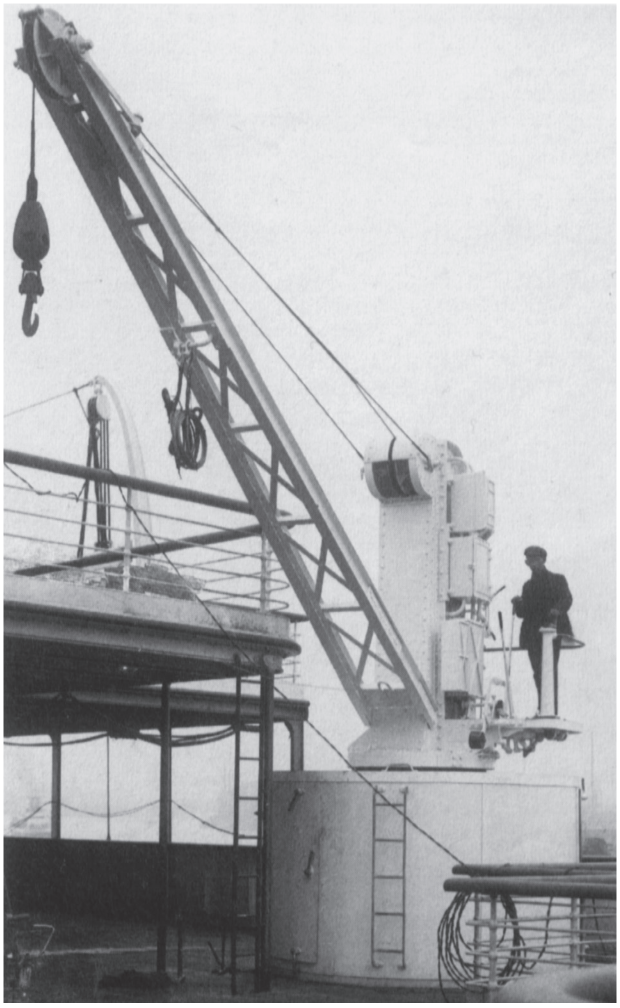
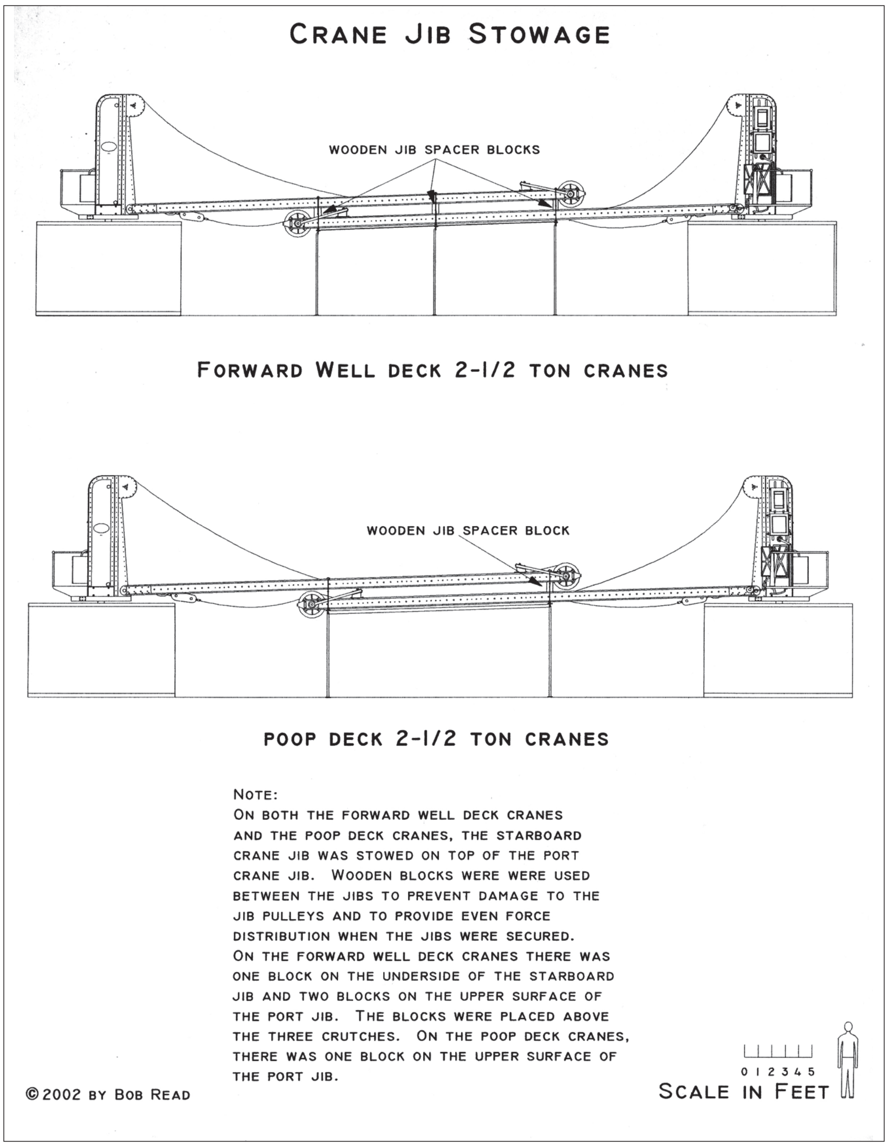


Fig. 21-3 **Crane on Promenade Deck** – One of *Olympic*'s 30cwt A Deck cranes from a period Stothert & Pitt advertisement. *(Robert Hahn collection)*

crane, stepped to the mast as a swinging boom. It was 64ft 0in long and 13in in diameter, was designed for 6-ton loads and came complete with tackle utilizing hemp-clad wire rope. The lower end or 'heel' of the derrick was pivoted, allowing it to move both vertically and horizontally. The tackle at the upper end, or head, supported, raised and lowered the derrick and was known as the topping lift. Rotating the boom about its base, as well as steadying it in position, was accomplished by other tackle rigged between the head of the derrick and various attachment points along the Well Deck bulwarks. These tackles were known as guys and in working the derrick were always tended simultaneously: by hauling on one while slacking off on the other, the lateral movement of the derrick was under control at all times.

The loads themselves were hoisted or lowered by tackle at the derrick head. A tackle with two blocks was used for heavier loads; gin blocks were used for lighter loads. The hauling part of these lines all led down to the winches


CRANE JIB STOWAGE
WOODEN JIB SPACER BLOCKS
FORWARD WELL DECK 2-1/2 TON CRANES
WOODEN JIB SPACER BLOCK
POOP DECK 2-1/2 TON CRANES
0 1 2 3 4 5
SCALE IN FEET

NOTE:
ON BOTH THE FORWARD WELL DECK CRANES AND THE POOP DECK CRANES, THE STARBOARD CRANE JIB WAS STOWED ON TOP OF THE PORT CRANE JIB. WOODEN BLOCKS WERE WERE USED BETWEEN THE JIBS TO PREVENT DAMAGE TO THE JIB PULLEYS AND TO PROVIDE EVEN FORCE DISTRIBUTION WHEN THE JIBS WERE SECURED.
ON THE FORWARD WELL DECK CRANES THERE WAS ONE BLOCK ON THE UNDERSIDE OF THE STARBOARD JIB AND TWO BLOCKS ON THE UPPER SURFACE OF THE PORT JIB. THE BLOCKS WERE PLACED ABOVE THE THREE CRUTCHES. ON THE POOP DECK CRANES, THERE WAS ONE BLOCK ON THE UPPER SURFACE OF THE PORT JIB.

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Fig. 21-4 **Jib Stowage** – This illustration shows the crutches that supported the jibs for the cranes in the forward Well Deck (top) and Poop Deck (bottom). *(Illustration Bob Read)*

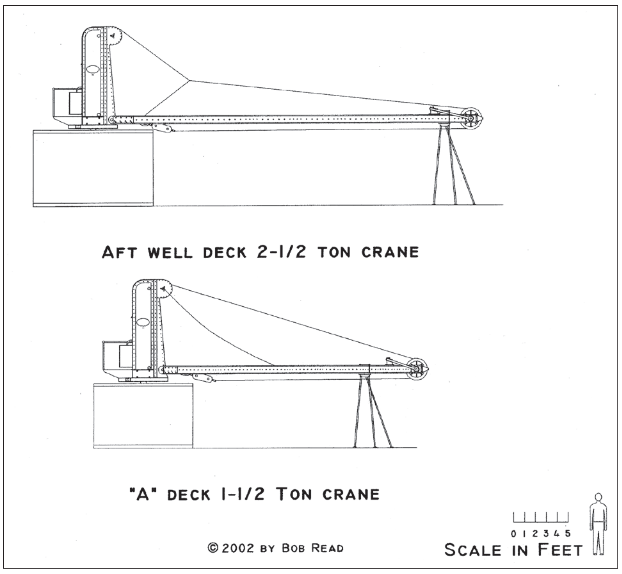
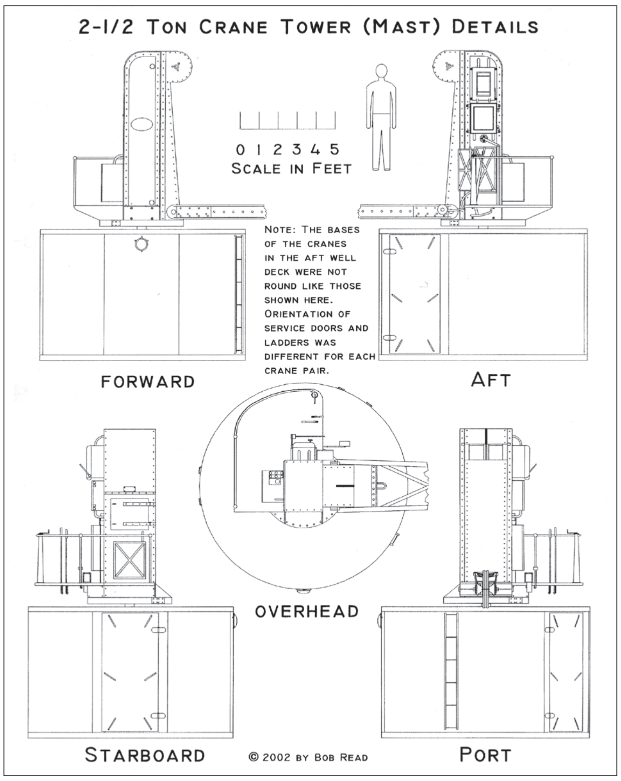

AFT WELL DECK 2-1/2 TON CRANE
"A" DECK 1-1/2 TON CRANE
©2002 BY BOB READ
0 1 2 3 4 5
SCALE IN FEET

Fig. 21-5 **Jib Stowage** – This illustration shows the crutches for the cranes in the after Well Deck (top) and A Deck (bottom). *(Illustration by Bob Read)*

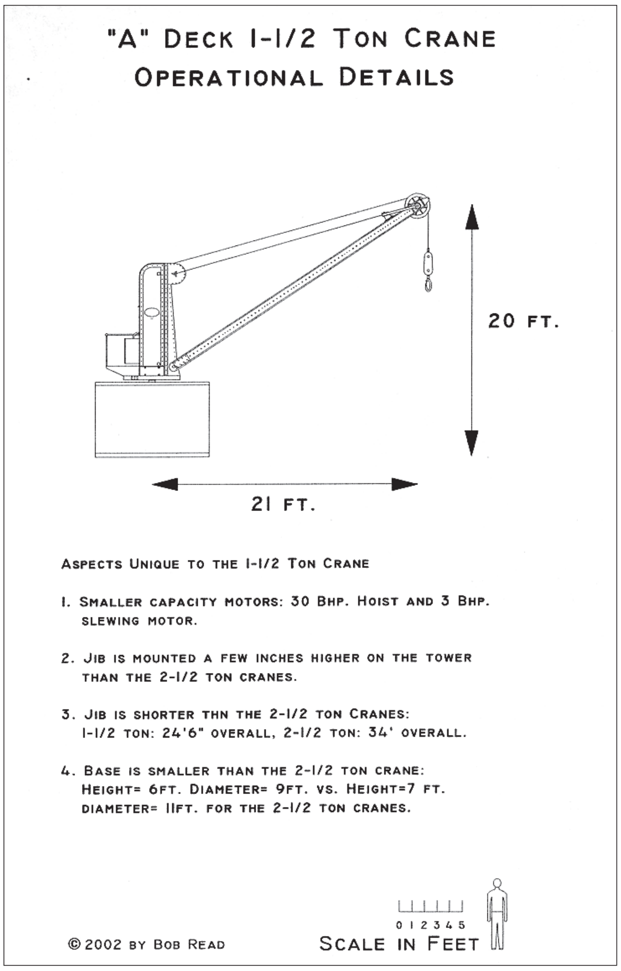
on deck. Multiple lines – called cargo runners – could be worked simultaneously adding additional gin blocks to the boom. The gin blocks could also be positioned in the center of the boom, rather than the head, if the derrick was being used to load cargo into the holds from the Well Deck rather than from the dock. In this case, a second tackle similar to the topping lift was rigged from the mast to the center of the derrick at the gin blocks to support it in the center and avoid buckling.

The derrick was stowed against the mast with clips when not in use. Provision was also made for installation of a similar derrick on the forward face of the mast, a hinged socket being attached for this purpose. Forward derricks for the *Olympic*-class were probably stowed at the White Star Line docks at which these ships would call. There are no photographs showing *Titanic* with her forward derrick fitted; however, *Olympic* was photographed with a forward derrick in place while at Harland & Wolff for repairs in 1912.


2-1/2 TON CRANE TOWER (MAST) DETAILS
0 1 2 3 4 5
SCALE IN FEET
FORWARD
AFT
OVERHEAD
STARBOARD
PORT
© 2002 BY BOB READ

NOTE: THE BASES OF THE CRANES IN THE AFT WELL DECK WERE NOT ROUND LIKE THOSE SHOWN HERE. ORIENTATION OF SERVICE DOORS AND LADDERS WAS DIFFERENT FOR EACH CRANE PAIR.

Fig. 21-6 **Details of Crane Masts** – This illustrates the cranes fitted in the Well Decks and on the Poop Deck. *(Illustration by Bob Read)*


"A" DECK 1-1/2 TON CRANE
OPERATIONAL DETAILS
20 FT.
21 FT.
© 2002 BY BOB READ
0 1 2 3 4 5
SCALE IN FEET

ASPECTS UNIQUE TO THE 1-1/2 TON CRANE

1. SMALLER CAPACITY MOTORS: 30 BHP. HOIST AND 3 BHP. SLEWING MOTOR.
2. JIB IS MOUNTED A FEW INCHES HIGHER ON THE TOWER THAN THE 2-1/2 TON CRANES.
3. JIB IS SHORTER THN THE 2-1/2 TON CRANES: 1-1/2 TON: 24'6" OVERALL, 2-1/2 TON: 34' OVERALL.
4. BASE IS SMALLER THAN THE 2-1/2 TON CRANE: HEIGHT= 6FT. DIAMETER= 9FT. VS. HEIGHT=7 FT. DIAMETER= 11FT. FOR THE 2-1/2 TON CRANES.

Fig. 21-8 **Operational Details of A Deck Cranes.** *(Illustration by Bob Read)*

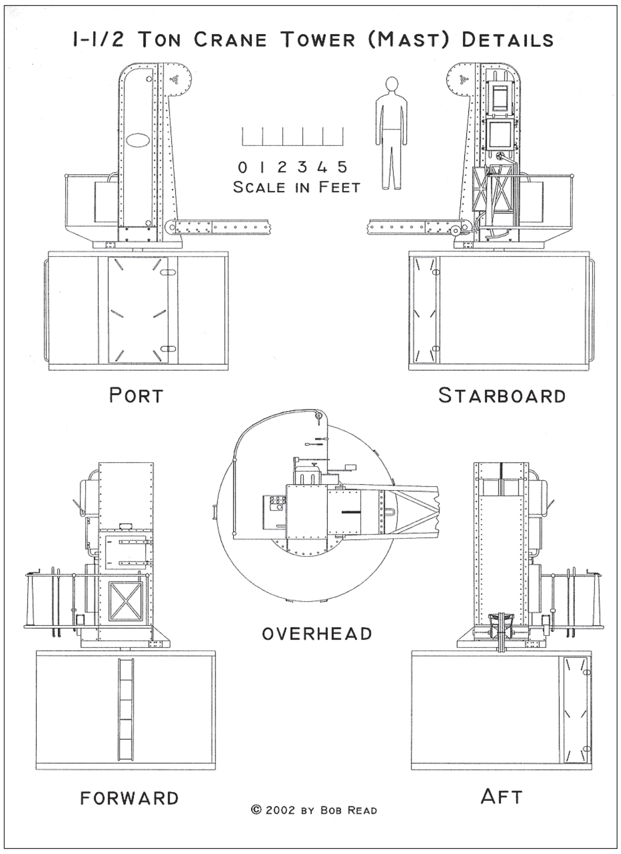

1-1/2 TON CRANE TOWER (MAST) DETAILS
0 1 2 3 4 5
SCALE IN FEET
PORT
STARBOARD
OVERHEAD
FORWARD
AFT
© 2002 BY BOB READ

Fig. 21-7 **Details of Crane Masts** – This illustrates the smaller cranes fitted on the after end of A Deck. *(Illustration by Bob Read)*

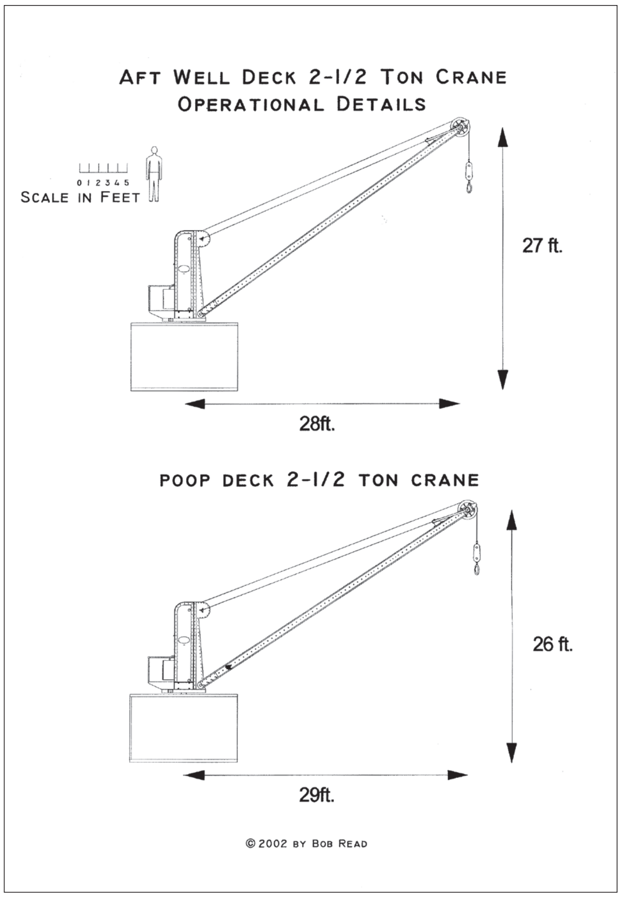
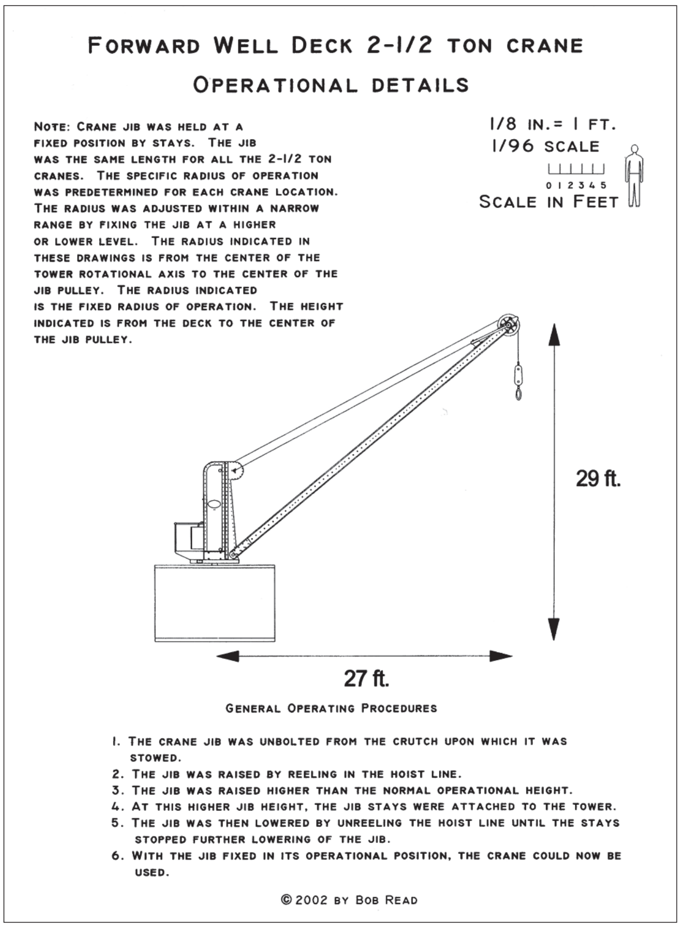

AFT WELL DECK 2-1/2 TON CRANE
OPERATIONAL DETAILS
0 1 2 3 4 5
SCALE IN FEET
27 ft.
28ft.
POOP DECK 2-1/2 TON CRANE
26 ft.
29ft.
© 2002 BY BOB READ

Fig. 21-9 **Operational Details of After Well Deck and Poop Deck Cranes.** *(Illustration by Bob Read)*


Forward Well Deck 2-1/2 ton crane
Operational details
1/8 in. = 1 ft.
1/96 scale
0 1 2 3 4 5
Scale in Feet
29 ft.
27 ft.

Note: Crane jib was held at a fixed position by stays. The jib was the same length for all the 2-1/2 ton cranes. The specific radius of operation was predetermined for each crane location. The radius was adjusted within a narrow range by fixing the jib at a higher or lower level. The radius indicated in these drawings is from the center of the tower rotational axis to the center of the jib pulley. The radius indicated is the fixed radius of operation. The height indicated is from the deck to the center of the jib pulley.

General Operating Procedures

1. The crane jib was unbolted from the crutch upon which it was stowed.
2. The jib was raised by reeling in the hoist line.
3. The jib was raised higher than the normal operational height.
4. At this higher jib height, the jib stays were attached to the tower.
5. The jib was then lowered by unreeling the hoist line until the stays stopped further lowering of the jib.
6. With the jib fixed in its operational position, the crane could now be used.

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Fig. 21-10 **Operational Details of Forward Well Deck Crane.** *(Illustration by Bob Read)*

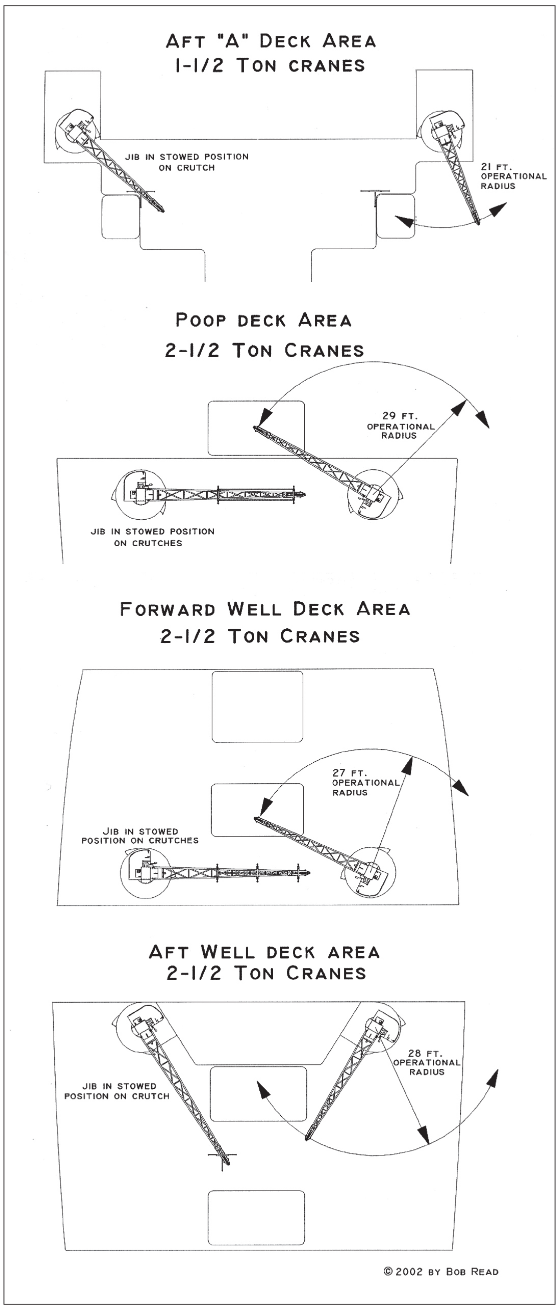
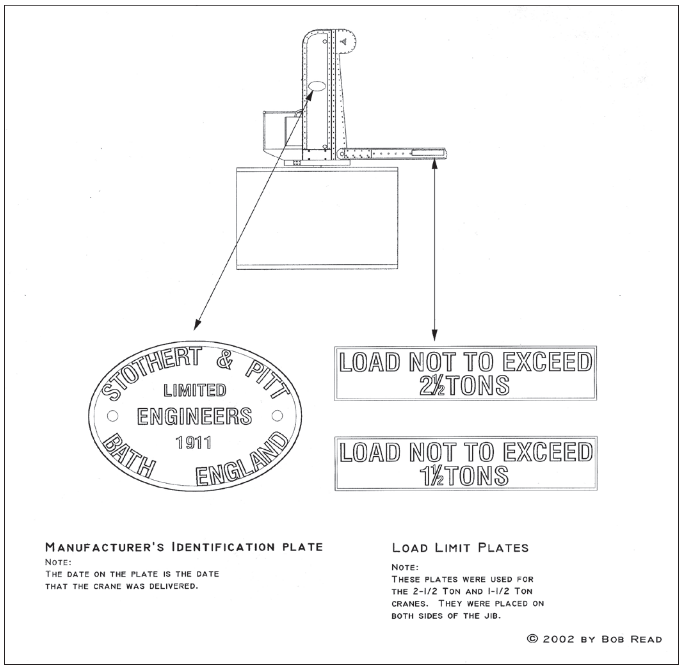

Aft "A" Deck Area
1-1/2 Ton cranes
Jib in stowed position on crutch
21 ft. operational radius
Poop deck Area
2-1/2 Ton Cranes
29 ft. operational radius
Jib in stowed position on crutches
Forward Well Deck Area
2-1/2 Ton Cranes
27 ft. operational radius
Jib in stowed position on crutches
Aft Well deck area
2-1/2 Ton Cranes
Jib in stowed position on crutch
28 ft. operational radius
© 2002 by Bob Read

Fig. 21-11 **Diagram of Crane Radii**. *(Illustration by Bob Read)*


Stothert & Pitt
Limited
Engineers
1911
Bath England
LOAD NOT TO EXCEED
2½TONS
LOAD NOT TO EXCEED
1½TONS

Manufacturer's Identification plate

Note:
The date on the plate is the date that the crane was delivered.

Load Limit Plates

Note:
These plates were used for the 2-1/2 Ton and 1-1/2 Ton cranes. They were placed on both sides of the jib.

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Fig. 21-12 **Manufacturer's Plate and Capacity Signs on Cranes** . *(Illustration by Bob Read)*

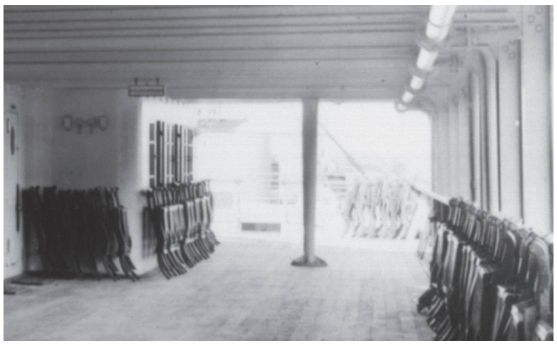


Fig. 21-13 **Crane Step** – One of *Olympic*'s A Deck crane steps as seen from B Deck. The large casting at deck level was called a 'step plate.'

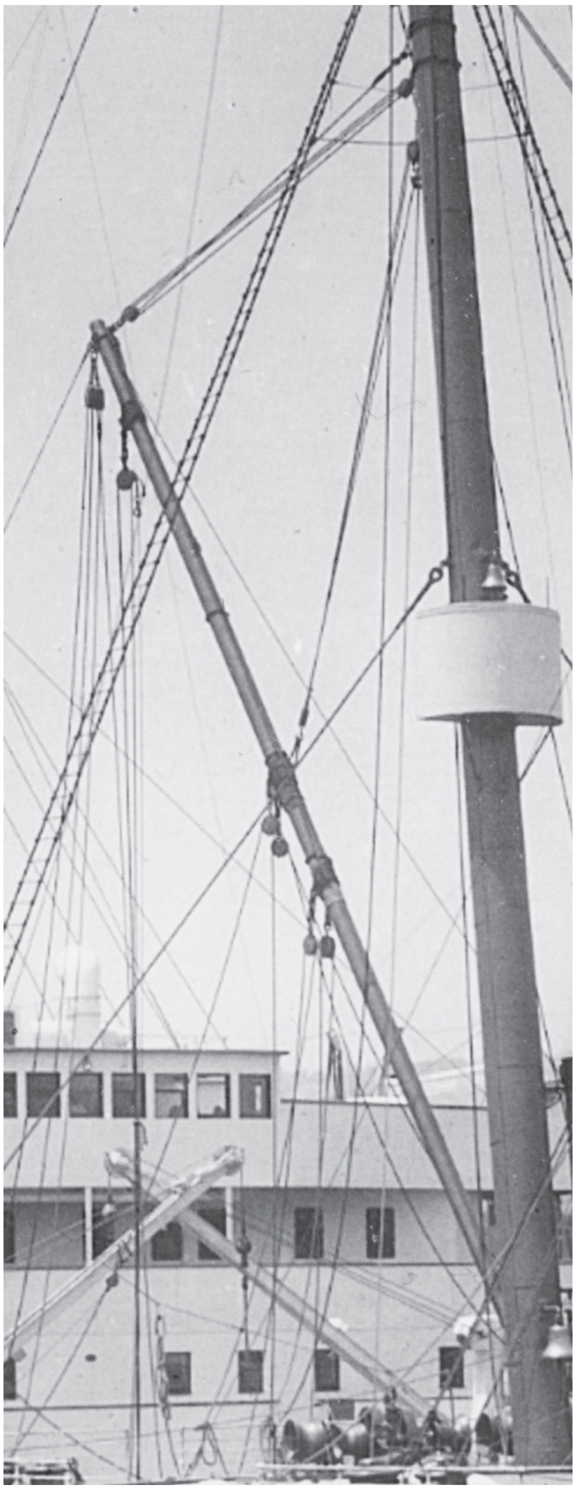


Fig. 21-14 **Foremast Derrick on *Olympic*** – *Olympic*'s derrick in use on the after side of the foremast at New York in 1911. This image gives an especially clear view of the topping lift, used to raise and lower the boom. Also note the numerous gin blocks and cargo runners rigged to the head and the midsection of the boom. *(Josha Inglis collection)*

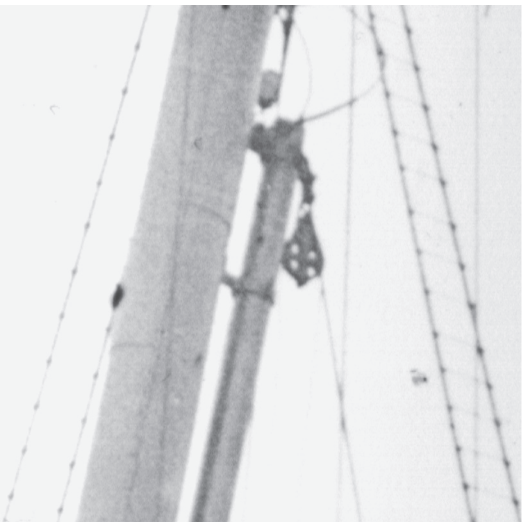


Fig. 21-15 **Foremast Derrick on *Titanic*** – This image of *Titanic*'s derrick shows the bracket on the mast, used to secure the derrick when it was stowed against the mast. In this image the derrick is rigged with a single gin block.

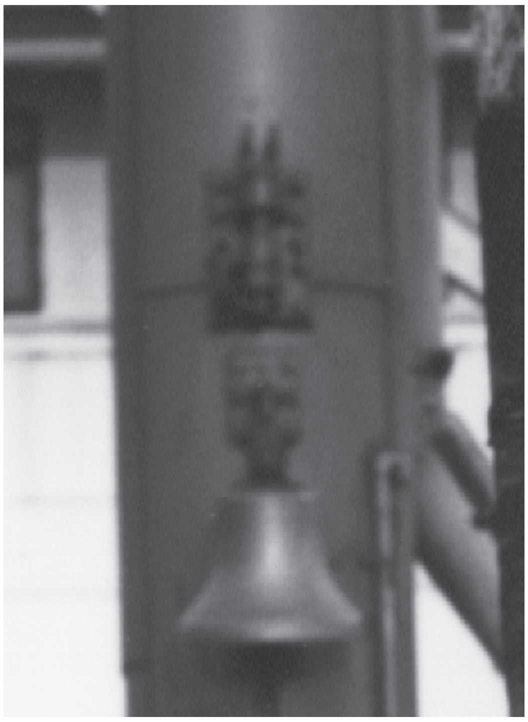


Fig. 21-16 **Derrick Step** – In this image from *Olympic*, a derrick step can be seen above the bell. *Titanic*'s lower mast bell was located on the aft side of the mast rather than on the fore side as on *Olympic*. A second bell was located at the Crow's-nest level.

Cargo spans

For cargo handling, two wire rope spans were rigged to an eyelet on the foremast near the top of the ratline shrouds. These were the cargo spans, of 3½in circumference (1⅛in diameter) flexible steel wire rope, which led to pad eyes located above the wheelhouse. Gin blocks with cargo runners were rigged near the center of the cargo spans directly above the hatches, with cargo runners rove through the blocks. As with the cargo runners on the derrick, the winches on deck were used to raise cargo in and out of the holds. A similar arrangement was

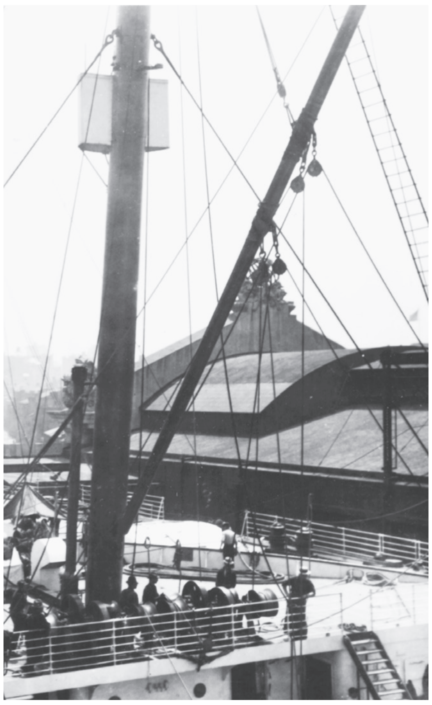


Fig. 21-17 ***Olympic*'s Derrick, Looking Forward** – Another view of *Olympic*'s derrick in use at New York. Like the previous image, this was taken on the occasion of her maiden voyage. This image gives a good view of the numerous cargo runners in place, as well as the steam winches used in conjunction with them.

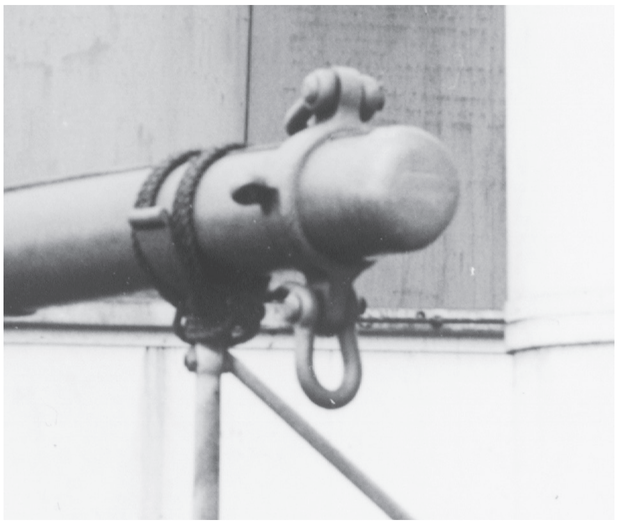


Fig. 21-18 **Close-up of Derrick Head** – Enlargement of the head of a derrick aboard another Harland & Wolff ship. The derrick head in this example is the same as *Titanic*'s, with the exception of the support brace shown here, as the derrick in this photograph was stowed horizontally.

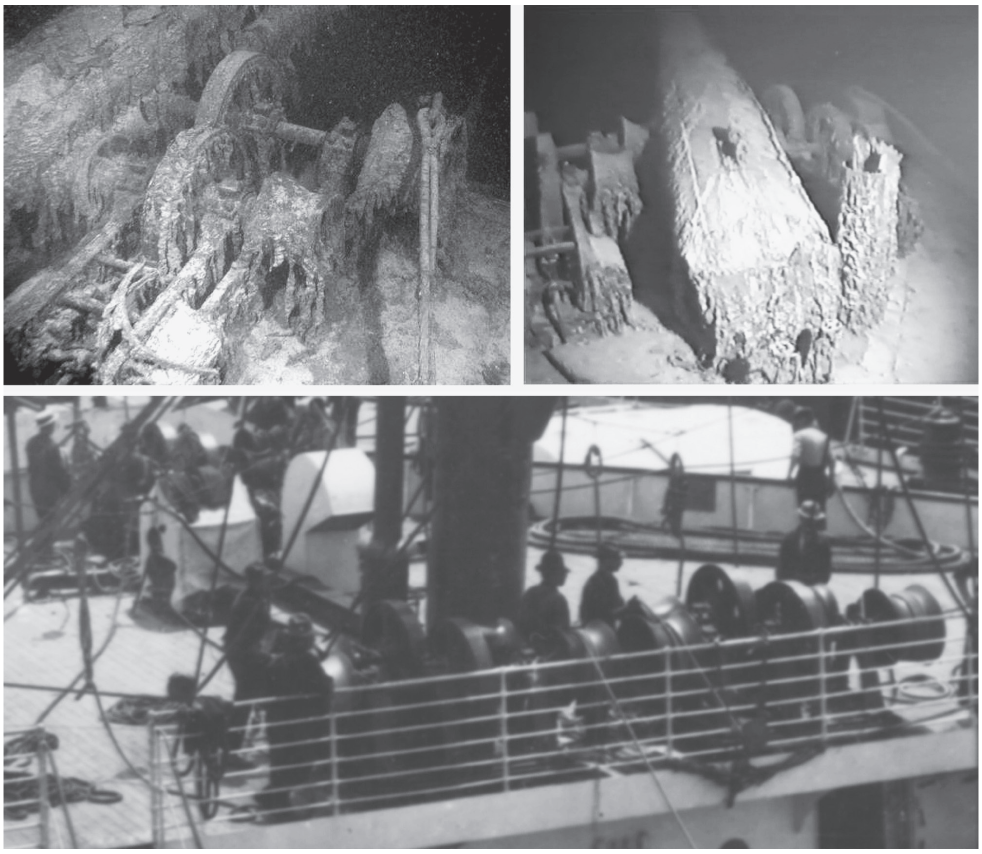
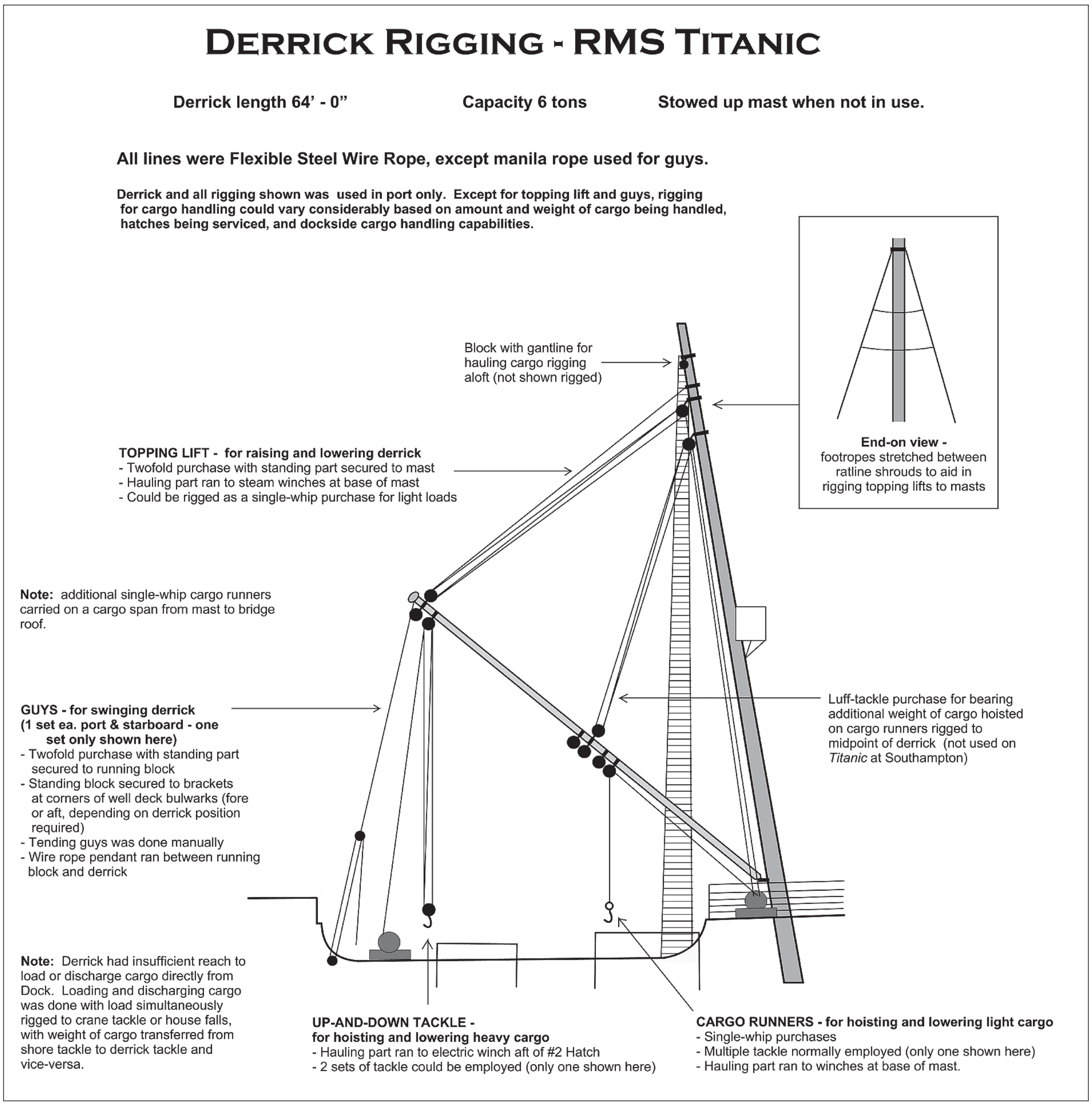


Fig. 21-19 **Steam Winches** – The images at top show the steam winches abaft *Titanic*'s foremast, as seen on the wreck. At bottom, these same winches are seen in use aboard the *Olympic* at New York on her maiden voyage in 1911. *(Wreck images courtesy Steve Rigby and Bernhard Funk;* Olympic *image from authors' collection)*

provided for a cargo span on the forward side of the mast to service the No.1 Hold through the hatch on the Forecastle Deck utilizing the steam winch at that location. When in use, the cargo span at this location was secured to one of several chain attachment points along the forward edges of the Forecastle Deck.

Steam winches

Located on the Forecastle Deck abaft the mast, and also abaft the coaming of the No.1 Hatch, were three black-painted Harland & Wolff single-purchase steam winches, with cylinders having an 8in x 14in bore and stroke. Each winch was fitted with four drums, or 'whipping ends'. These winches were used for loading cargo through the



Derrick Rigging - RMS Titanic

Derrick length 64' - 0" **Capacity 6 tons** **Stowed up mast when not in use.**

All lines were Flexible Steel Wire Rope, except manila rope used for guys.

Derrick and all rigging shown was used in port only. Except for topping lift and guys, rigging for cargo handling could vary considerably based on amount and weight of cargo being handled, hatches being serviced, and dockside cargo handling capabilities.

Block with gantline for hauling cargo rigging aloft (not shown rigged)

End-on view - footropes stretched between ratline shrouds to aid in rigging topping lifts to masts

TOPPING LIFT - for raising and lowering derrick
- Twofold purchase with standing part secured to mast
- Hauling part ran to steam winches at base of mast
- Could be rigged as a single-whip purchase for light loads

Note: additional single-whip cargo runners carried on a cargo span from mast to bridge roof.

GUYS - for swinging derrick (1 set ea. port & starboard - one set only shown here)
- Twofold purchase with standing part secured to running block
- Standing block secured to brackets at corners of well deck bulwarks (fore or aft, depending on derrick position required)
- Tending guys was done manually
- Wire rope pendant ran between running block and derrick

Luff-tackle purchase for bearing additional weight of cargo hoisted on cargo runners rigged to midpoint of derrick (not used on *Titanic* at Southampton)

Note: Derrick had insufficient reach to load or discharge cargo directly from Dock. Loading and discharging cargo was done with load simultaneously rigged to crane tackle or house falls, with weight of cargo transferred from shore tackle to derrick tackle and vice-versa.

UP-AND-DOWN TACKLE - for hoisting and lowering heavy cargo
- Hauling part ran to electric winch aft of #2 Hatch
- 2 sets of tackle could be employed (only one shown here)

CARGO RUNNERS - for hoisting and lowering light cargo
- Single-whip purchases
- Multiple tackle normally employed (only one shown here)
- Hauling part ran to winches at base of mast.

Fig. 21-20 **Derrick Rigging Diagram**. *(Illustration by Art Braunschweiger)*

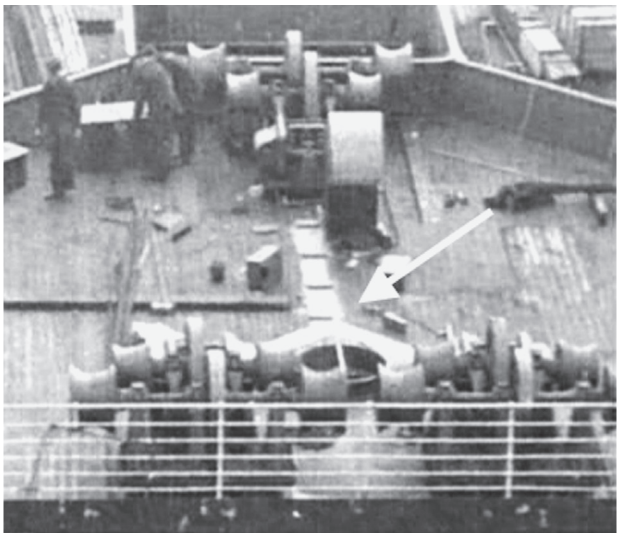


Fig. 21-21 **Steam Winch During Construction** – This image, taken from a newsreel film, shows *Olympic*'s Forecastle Deck under construction. The Y-shaped object on deck between the mast hole and the winch abaft the No.1 Hatch was a shroud covering the steam supply and exhaust return pipes.

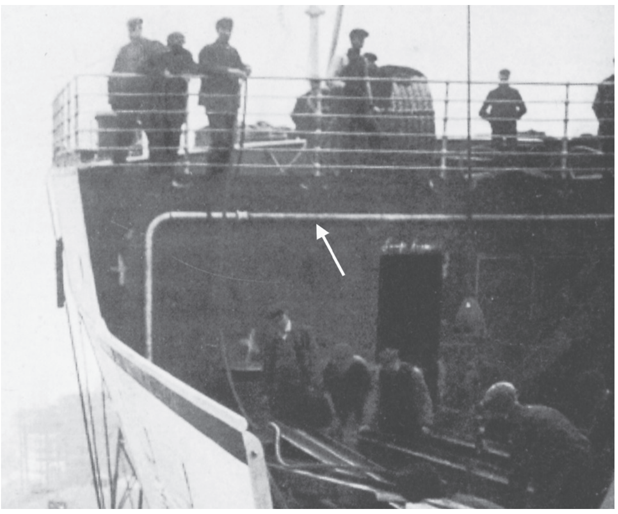


Fig. 21-22 **Temporary Steam Exhaust Pipe for Winches** – In this image of *Olympic* during construction, a pipe (indicated by arrow) is visible running along the forward bulkhead of the forward Well Deck. This pipe led from the steam winches and directed exhaust steam to an outlet through the shell plating near the load line when the condensers were not in use. *(Art Braunschweiger collection)*

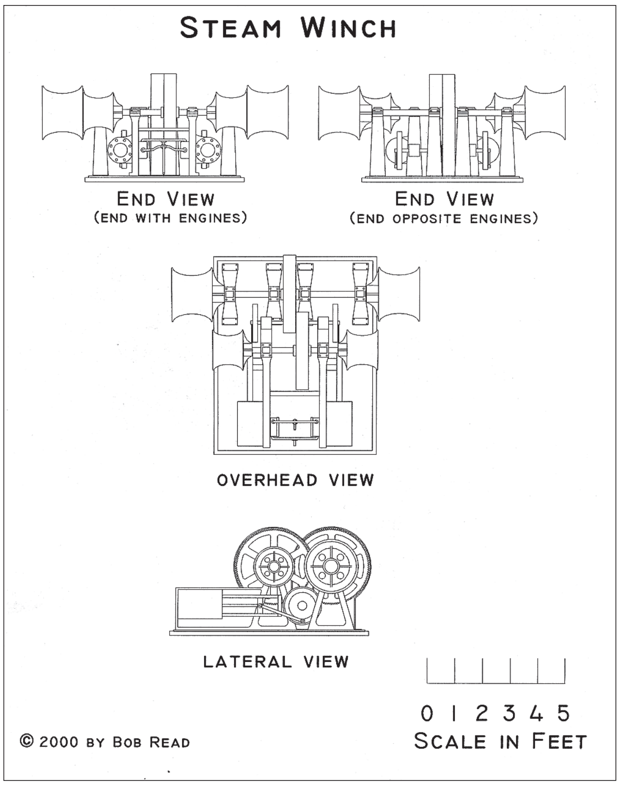
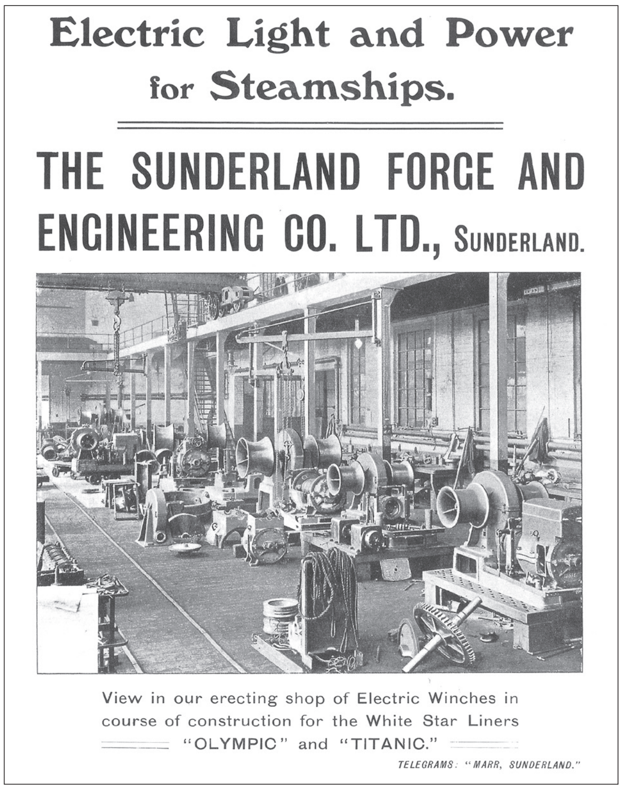


Fig. 21-23 **Illustration of Steam Winch**. *(Illustration by Bob Read)*

Nos 1 and 2 Hatches, as well as for tending the topping lift of the derrick. The winches were fed steam from pipes mounted above the deck level, supported on cast-iron stools and covered with protective metal shrouds.

The feed and exhaust piping for the steam winches was run from the main boiler rooms, through the Fireman's Tunnel and up a trunk to the Forecastle Deck. Being that the steam winches were part of *Titanic*'s auxiliary machinery, they were powered with steam from the auxiliary steam range, most often supplied with steam from Boiler Room No.1 while in port. When the main condensers were on line, the exhaust steam from the winches would be fed back through the system as was usual practice to conserve resources. When in port, the exhaust steam was recovered by the auxiliary condenser, or in the rare instances when all of the condensers were off line, the exhaust steam of the winches was directed into a pipe which exited the side of the ship down near the load waterline. A pipe can be seen in photographs of *Olympic*'s and *Titanic*'s forward Well Decks at the top of the bulkhead over the lamp room door. This pipe was used for draining off water from the machinery and for the non-condensing exhaust of waste steam. Pictures exist of an odd haze of steam emitting from the port side of *Olympic*'s bow while she was at Harland & Wolff for repairs. This is the exhaust steam from the winches being discharged through a specially fitted scupper pipe and side discharge opening while the ship's condensers



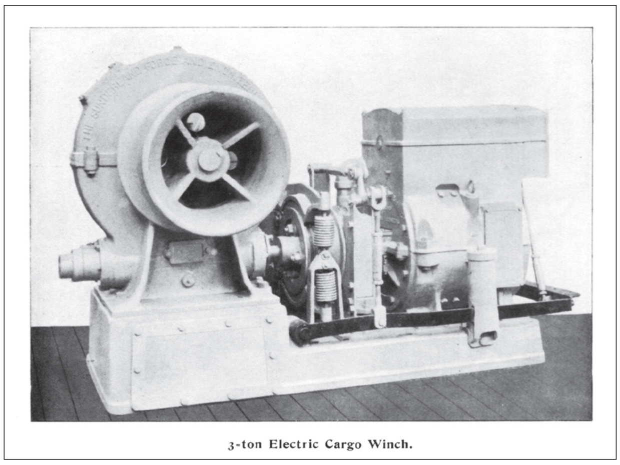
Electric Light and Power
for Steamships.

THE SUNDERLAND FORGE AND ENGINEERING CO. LTD., SUNDERLAND.

View in our erecting shop of Electric Winches in course of construction for the White Star Liners "OLYMPIC" and "TITANIC."

TELEGRAMS: "MARR, SUNDERLAND."

Fig. 21-24 **Sunderland Forge Advertisement** – An original advertisement for the Sunderland Forge and Engineering Co. Ltd, which supplied the electric winches for *Titanic. (*The Shipbuilder*/Authors' collection)*



3-ton Electric Cargo Winch.

Fig. 21-25 **Electric Winch** – An image of a 3-ton electric winch as it appeared in the period journal *The Shipbuilder.*

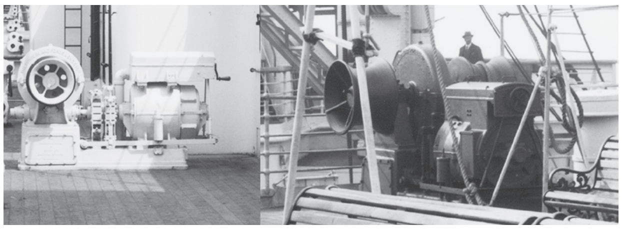


Fig. 21-26 **Electric Winches on Boat and Poop Decks** – Two images of *Olympic*'s electric winches as seen later in her career. At left is the winch on the starboard side of the Officers' Quarters deckhouse; at right is the one on the Poop Deck. *(Both images authors' collection)*

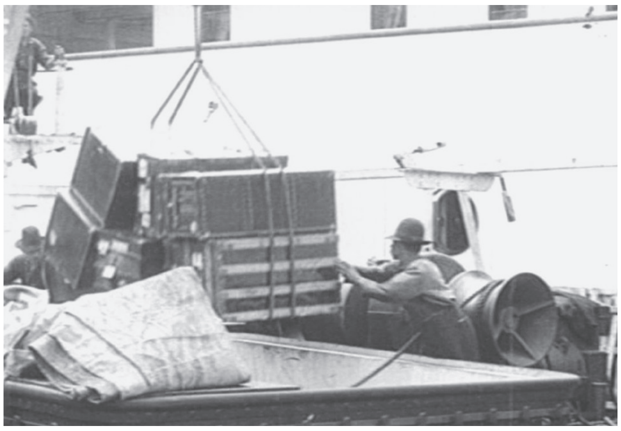


Fig. 21-27 **Electric Winch in Well Deck** – The electric winch in *Olympic*'s forward Well Deck, aft of the No.3 Hatch. This photograph gives a good appreciation for the size of these winches. The horizontal metal bar in the background behind the deckhand is part of the jib crutch for the forward set of cranes.

were off line. Another image exists of *Olympic*'s stern while she was in dry dock, in which an elbow-shaped pipe is seen jutting out from a porthole. This, too, was an exhaust steam pipe, albeit a temporary one, rigged by the shipyard plumbers to allow the use of the auxiliary steam engines on the Shelter Deck (C) while the fitting-out of the ship continued. These engines were used to power the capstans on the Poop Deck and the single capstan in the steering engine space.

Electric winches

Titanic was fitted with four electric winches on the Boat Deck to accommodate heaving in lifeboats. Painted dark green, with black whipping ends, these winches were designed to hoist a weight of 15cwt each.

Located in the forward Well Deck, aft of the No.3 (Bunker) Hatch, were two 3-ton electric winches used for loading cargo. The after Well Deck was fitted with one 3-ton winch, and the forward end of the Poop Deck was fitted with a fourth 3-ton winch. These were painted in the same color scheme as the Boat Deck winches.

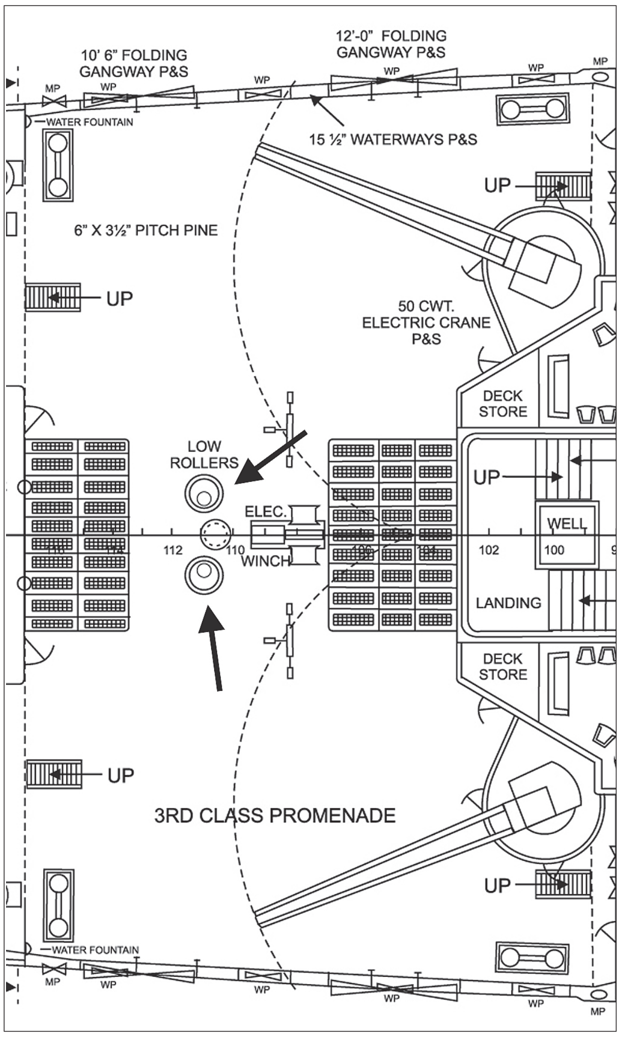


Fig. 21-28 **Low Rollers in After Well Deck** – In this plan view of the after Well Deck, the low rollers between the Nos 5 and 6 Hatches are indicated by arrows. *(Illustration by Bruce Beveridge)*

All winches were supplied by the Sunderland Forge and Engineering Co. Ltd. The winch motors were designed to be practically noise- and vibration-free, with a lifting speed of 100ft per minute at full load. The working parts and motors were made watertight as they were mounted on the decks and were fully exposed to weather. However, fitted canvas covers were placed over the winches if needed. The whipping ends were driven through worm gears totally encased in an oil bath. Ball thrust blocks were provided on the worm shafts. The motors were series-wound and contained all of the necessary control gear. Magnetic foot brakes were provided on each side of the winch, the latter being connected to a controller to prevent abuse of the motor by unskilled operators. Special attention was given to the electrical parts due to the damp salt-water conditions in which the machines operated.

Two electric winches, supplied by Chambers, Scott and Co. of Motherwell, were installed in the Reciprocating Engine Room in connection with the cylinder cover lifting gear. These winches were capable of hoisting 2 tons each.

Rollers

The winches could also be utilized to exert a lateral pull on a suspended load if it was necessary to shift the cargo to one side or the other as it was going into the hatch or out onto the deck. When necessary to exert a lateral pull in a direction opposite the side where the winch

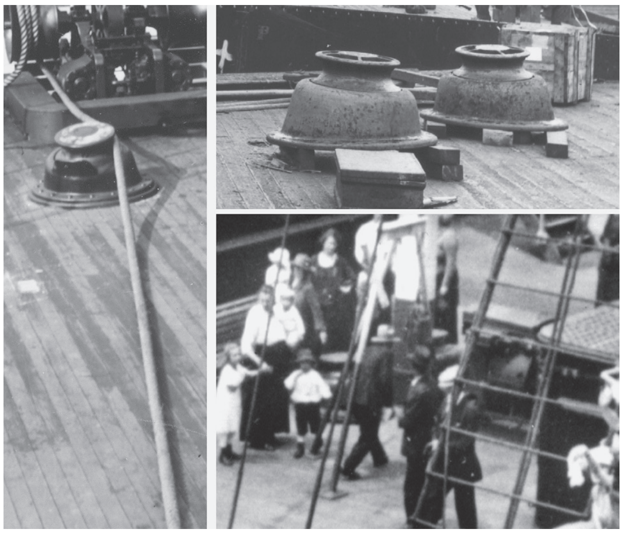


Fig. 21-29 **Low Rollers** – Low rollers as seen on different Harland & Wolff ships. These rollers were usually fitted with a guide piece that projected out on one side for the rope that would pass across the roller. The image at lower right was taken aboard *Olympic* later in her career after the hatch coamings had been raised. *(H&W/Authors' collection)*

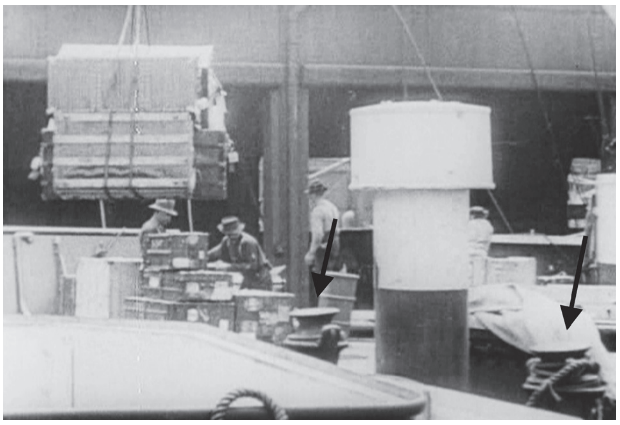


Fig. 21-30 **Elevated Rollers** – In this frame from a newsreel film, the elevated rollers on *Olympic* can be seen (indicated by arrows). These had an 'ear' or guide located only on their inboard sides and were somewhat like their after Well Deck counterparts.

was located, rollers on deck were utilized. By passing a line around a roller located on the opposite side of the hatch, the winch could exert a pulling force in a direction toward that side.

Located midway between the Nos 5 and 6 Hatches was a pair of low rollers. These consisted of a wheel or fairlead mounted on a circular cast-iron base. In the forward Well Deck, midway between the Nos 2 and 3 Hatches, was a set of fairleads mounted on pedestals which extended above the height of the hatch coamings. These devices, like their after Well Deck counterparts, were used in the same way to assist in the loading of cargo.

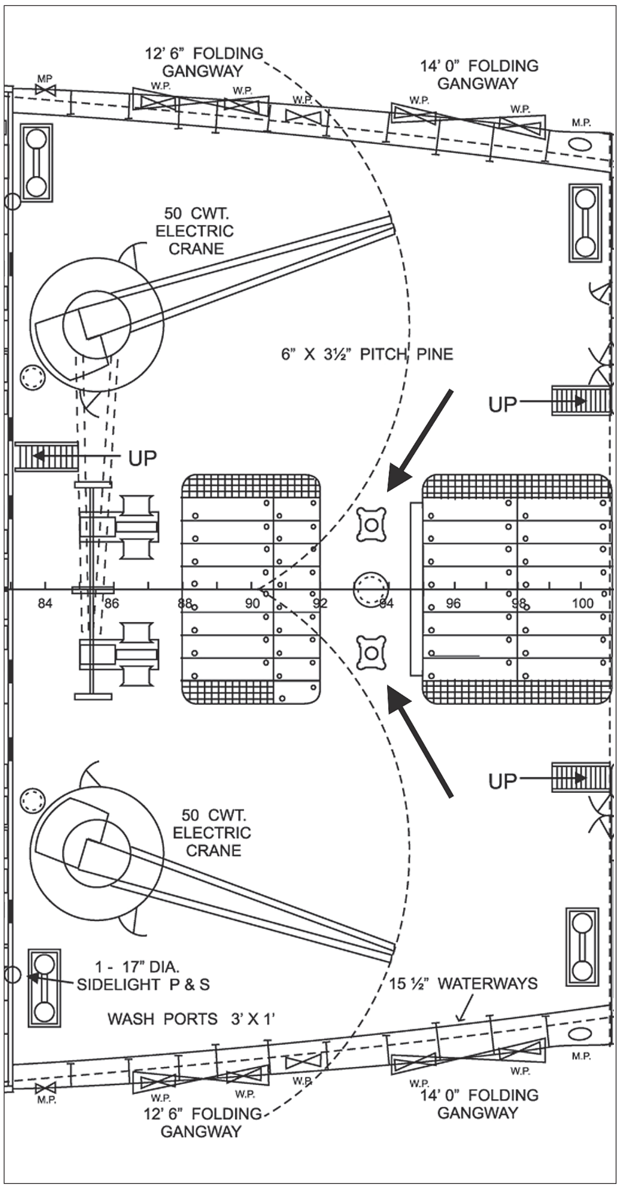


Fig. 21-31 **Elevated Rollers in Forward Well Deck** – In this plan view, the two elevated fairlead rollers in the forward Well Deck are indicated by arrows. *(Illustration by Bruce Beveridge)*

Wire rope

For the majority of lines used in cargo handling, including the crane lines, flexible steel wire rope was used. Although all types of wire rope had a hemp core, the number of individual strands was far greater in flexible wire rope and made it suitable for taking tight turns around pulley sheaves or winch drums. Wire rope is dealt with further in Chapter 13 in this volume.

Tackles and purchases

A purchase is a mechanical device used to increase an applied pull or force. A tackle (pronounced 'taykle') is a purchase consisting of a rope or cable rove through the

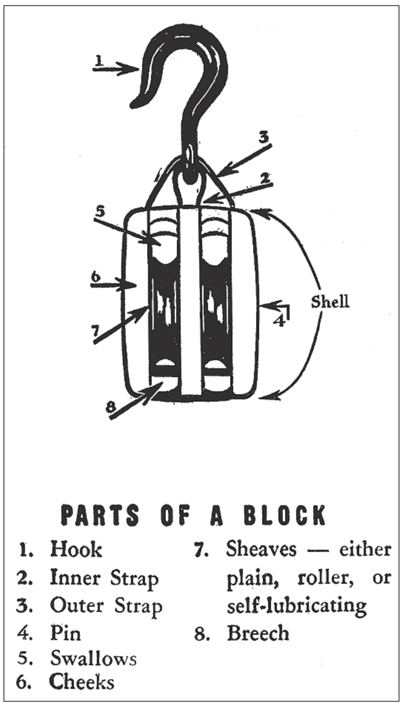

1
2
3
4
5
6
7
8
Shell
PARTS OF A BLOCK
1. Hook
2. Inner Strap
3. Outer Strap
4. Pin
5. Swallows
6. Cheeks
7. Sheaves — either plain, roller, or self-lubricating
8. Breech

Fig. 21-32 **Parts of a Block**.

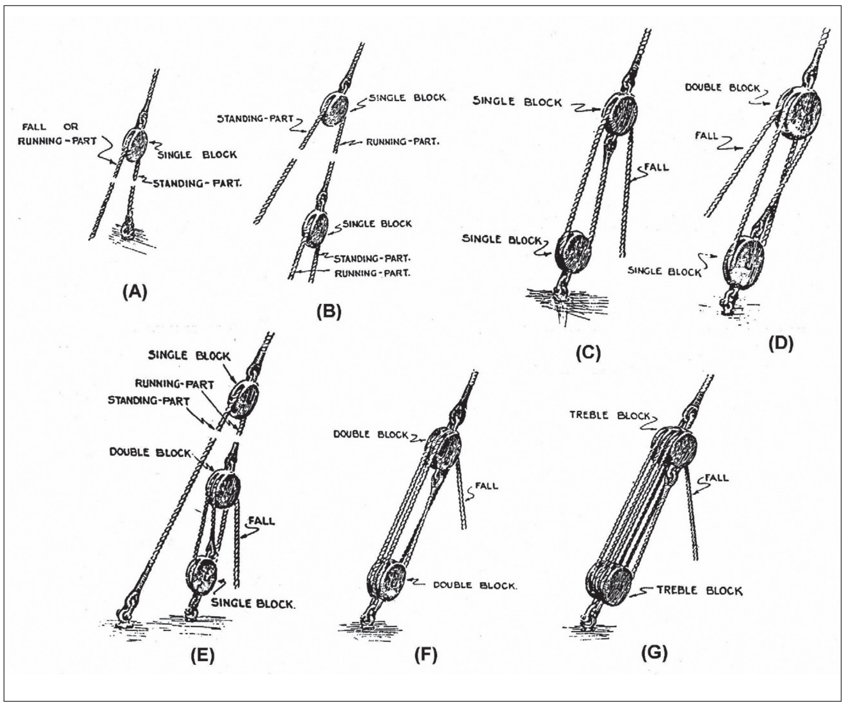

FALL OR RUNNING-PART
SINGLE BLOCK
STANDING-PART
(A)
STANDING-PART
SINGLE BLOCK
RUNNING-PART
SINGLE BLOCK
STANDING-PART
RUNNING-PART
(B)
SINGLE BLOCK
FALL
SINGLE BLOCK
(C)
DOUBLE BLOCK
FALL
SINGLE BLOCK
(D)
SINGLE BLOCK
RUNNING-PART
STANDING-PART
DOUBLE BLOCK
FALL
SINGLE BLOCK
(E)
DOUBLE BLOCK
FALL
DOUBLE BLOCK
(F)
TREBLE BLOCK
FALL
TREBLE BLOCK
(G)

Fig. 21-33 **Types of Purchases** – The following purchases are identified by their names followed by the mechanical advantage which they provided, less friction: A – Single-whip purchase, 1:1; B – Single-whip purchase rigged to another single-whip, 1:1; C – Gun-tackle purchase, 2:1; D – Luff-tackle purchase, 3:1; E – Luff-tackle purchase rigged to a single-whip, 3:1; (F) Twofold purchase, 4:1; (G) Threefold purchase, 6:1. Examples of A, B and C could all be found in use for cargo-handling purposes aboard *Titanic*. F could be found in the guys of the anchor crane. (F could also be found in the falls of the two emergency cutters, while G was employed in the falls of the lifeboats.)

sheaves in two or more blocks in such a way that any pull applied to its free end, or 'hauling part' is increased by an amount depending upon the number of sheaves in the blocks and the manner in which the rope is rove through them. The blocks are termed the standing block, which is fixed to or suspended from some point, and running or traveling block, which is connected to the object to be lifted. The 'fall' is the rope rove through the blocks, although sometimes this term is applied only to the line which is hauled upon. The size of a tackle is described by the size of its fall; a 3in twofold purchase for example, would be rove with a 3in fall, the size referring to the circumference of the rope used.

Mechanical advantage is the factor by which a mechanism multiplies the force put into it. The mechanical advantage of a block and tackle is approximately equal to the number of lines running between the standing and running blocks. For instance, a twofold purchase, which consists of two blocks each containing two sheaves, has four lines running between the blocks, giving it a mechanical advantage in theory of 4:1; in this instance, this would in theory allow, for example, the lifting of 300lb with a pulling force of only 75lb. The decrease in pulling force comes at a price, however, in the form of decreased lifting speed and an increase in the length of fall which must be pulled through the blocks, both in direct proportion to the theoretical mechanical advantage.

When calculating the actual (rather than theoretical) lifting capacity of any tackle, or in calculating the actual pulling force required to lift a given load, friction (resulting primarily from the sheave rotating around the pin) and the resulting reduction in mechanical advantage has to be taken into account. The friction within a tackle is generally calculated at roughly 10 per cent of the load per sheave. In the example given above, where there are a total of four sheaves, friction increases the effective total weight to be lifted by 40 per cent for a total of 420lb, meaning that the actual pulling force to lift 300lb with this tackle would be about 105lb.

Baggage and mail handling

The handling of passenger baggage is expounded upon in a separate chapter. However, it is worth noting here that passenger baggage marked 'Not Wanted On Voyage' was stowed in the hold under the supervision of one of the officers, at which point it became the responsibility of a Baggage Master. In most cases, the duty of supervising the stowage of cargo aboard ships of the White Star Line fell to the 2nd Officer, who had general charge of the

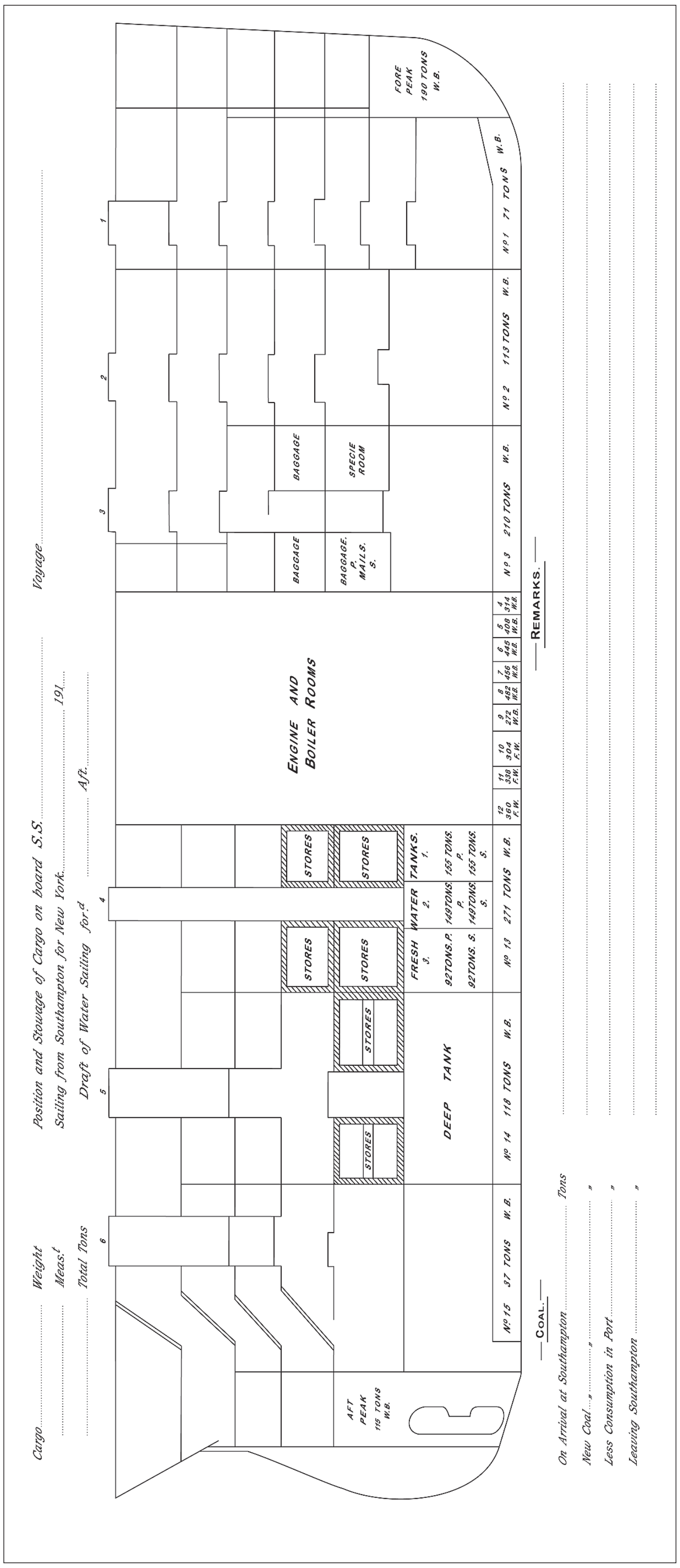

Cargo
Weight
Meas.t
Total Tons
Position and Stowage of Cargo on board S.S.
Sailing from Southampton for New York 191
Draft of Water Sailing for'd Aft
Voyage
FORE PEAK 190 TONS W.B.
Nº 1 71 TONS W.B.
Nº 2 113 TONS W.B.
Nº 3 210 TONS W.B.
BAGGAGE
SPECIE ROOM
BAGGAGE
BAGGAGE. P. MAILS. S.
ENGINE AND BOILER ROOMS
4 314 W.B.
5 408 W.B.
6 445 W.B.
7 456 W.B.
8 482 W.B.
9 272 W.B.
10 304 F.W.
11 338 F.W.
12 360 F.W.
STORES
FRESH WATER TANKS.
3. 92TONS.P. 92TONS.S.
2. 149TONS. P. 149TONS. S.
1. 155 TONS. P. 155 TONS. S.
Nº 13 271 TONS W.B.
DEEP TANK
Nº 14 118 TONS W.B.
Nº 15 37 TONS W.B.
AFT PEAK 115 TONS W.B.
1
2
3
4
5
6
COAL.
On Arrival at Southampton Tons
New Coal
Less Consumption in Port
Leaving Southampton
REMARKS.

Fig. 21-34 **Cargo Stowage Diagram** – On *Olympic* and *Titanic*, cargo diagrams were filled out to indicate where the various types of cargo were stowed. 2nd Officer Lightoller filled out one of these diagrams for *Titanic* before she sailed. *(Redrawn from original by Art Braunschweiger)*

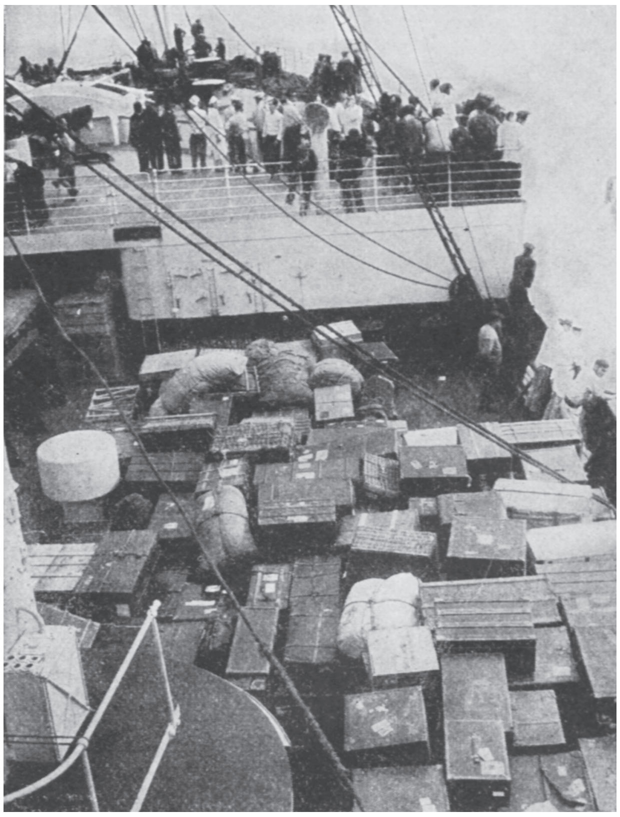


Fig. 21-35 **Baggage on *Olympic*** – Baggage is piled in *Olympic*'s forward Well Deck in this image from a White Star Line brochure of the late 1920s.

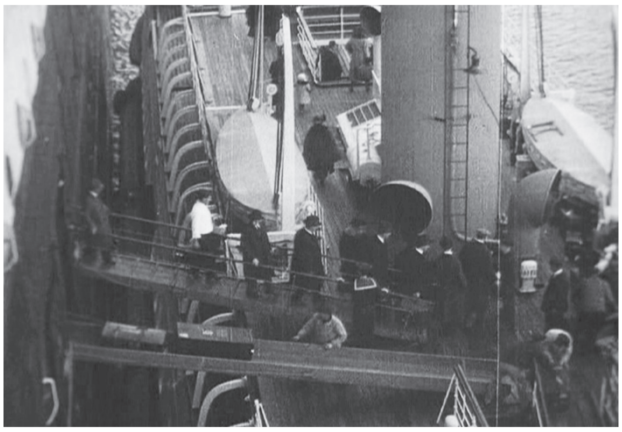


Fig. 21-36 **Offloading Baggage to Tender** – In this frame from an original White Star Line promotional film, passengers disembark from the Second Class main companionway on E Deck while some of their luggage is slid down a wooden chute to the top deck of the tender *Nomadic* at Cherbourg.

baggage hold. 'Not wanted' baggage was stowed in the Nos 2 and 3 Holds in areas reserved for that purpose, and at the Orlop Deck level the baggage filled up the space around the Specie Room. As it was always desirable in port to unload the baggage in the holds as quickly as possible, when approaching port the greater part of it was got up on deck well before coming alongside the dock. Once docked, the baggage was then transferred to shore for customs inspections. When necessary, especially when utilizing tenders as in Cherbourg or Queenstown, the ship's side doors were utilized. In this case, a wooden chute was utilized as well, 14ft long by 3ft wide in size, and the baggage was slid down to the dock or tender deck piece-by-piece.

Mail also comprised a significant part of *Titanic*'s cargo, as noted above. As a Royal Mail steamer, *Titanic* not only carried the mails, but sorted it en route. A Sea Post Office was located adjacent the First Class baggage area on the forward side of G Deck forward, and there was also a mailbag storage area below, occupying most of the starboard side between WTBs C and D. On board since Southampton were five clerks of the international Sea Post Service – three American and two British – each employed by the mail service of his respective country. Usually two British and two United States clerks would be carried on *Olympic* and *Titanic*, although when under special pressures such as Christmas, as many as eight could be employed. The position of Sea Post Clerk was an extremely prestigious one, reflected in their badge, uniform and salary. They were considered the 'best of the best' within their trade, and routinely sorted 60,000 pieces of mail each on a daily basis with few, if any, mistakes made. They were expected, quite literally, to guard the mail with their lives, and this accounts for their desperate efforts to drag hundreds of mailbags above the rising waters in the mailroom as *Titanic* was sinking. Even White Star Line regulations enjoined the Master to regard the security of the mails as secondary only to that of the passengers themselves.

The hours of duty were from 6.00 a.m. to 7.00 p.m. with an hour off for breakfast and another for lunch, Sunday being no exception. The shipping companies received payment from the postal authorities for providing accommodations to the clerks and also for the space devoted to sorting and stowage rooms.

A brief look at *Titanic*'s role in handling the mails is in order here. *Titanic* carried 3,365 mailbags, of which 1,758 had been loaded at Southampton, 1,412 at Cherbourg and 194 at Queenstown. In addition, there were between 700 and 800 parcel post shipments. In connection with these figures, it must be remembered that the majority of the bags contained 'direct' or 'transit' correspondence which was not handled in any way during the voyage, those being stored in the Mail Room on the Orlop Deck. On an average about 300 sacks were opened and sorted en route, although the number in an exceptionally heavy mail load could have been as high as 700.

For any mail that required sorting, prior to arrival at New York the clerks would have the sorted mail bundled with facing (routing) slips and sorted into mailbags according to their required destination. The task of sorting was a prodigious one: there was an average of 2,000 letters per mailbag, with New York City alone having 44 separate destinations.

Upon reaching New York, the mails were offloaded at Quarantine Station in Upper New York Bay off Clifton, Staten Island. Prior to docking at New York, all inbound Atlantic liners had to anchor off Quarantine where doctors of the Public Health and Marine Hospital Service conducted a health inspection of the passengers. Primarily oriented toward the immigrant passengers, the purpose was to prevent entry into the United States of anyone carrying infectious diseases. Despite the ship's huge size and passenger complement, though, *Titanic*'s officers would have anticipated clearing Quarantine with minimal delay owing to the ship's excellent sanitary conditions and the presence of a surgeon in the crew who was responsible for attesting to the passengers' health.

While the health inspectors were boarding from their launch for the health inspection, *Titanic* would have been met by one of two mail tenders, the *Postmaster General* or the newer 167ft *President*, onto which the mail would be offloaded under the supervision of one of the ship's Junior Officers. In fact, the mail would actually reach shore long before the first passenger stepped off the ship. Mail sacks on *Titanic* were offloaded to the tenders by being slid down wooden chutes 24ft x 3ft with sides 6in high. Also provided were canvas chutes 18ft x 6ft 2in in size.

A note is also worthwhile here about *Titanic*'s Specie Room, used for the transport of specie (gold and silver coinage) and bullion. Most first-class vessels had a specie room and from time to time transported great quantities of this valuable cargo. This was especially so of vessels in the transatlantic trade. The specie room on *Titanic* was constructed as a strong box located near the bottom of the vessel. Located towards the bottom of the No.3 Hatch trunk, the specie was loaded onboard first. Then, after the specie was in place, the hold surrounding the Specie Room was filled with the 'Not Wanted On Voyage' baggage as noted above. With hundreds of trunks in place, this effectively (and intentionally) made the specie inaccessible while the ship was at sea. The ship's Purser signed for the specie himself, although the Master was directly responsible for the property. Generally this cargo was unloaded as rapidly as possible, and of course taken away first.

OUTRIGGERS AND THE LOADING OF COAL

Titanic was fitted with special hinged outriggers mounted along the sides of the A Deck promenade bulwarks. Consisting of two sets of outriggers per side of the ship, these devices were swung out and secured with metal booms on each of the set for rigidity, the outrigger arms being tied to each other with steel wire rope. This design was original to Harland & Wolff, and would prove useful not only for loading the ship's bunkers and the coal and

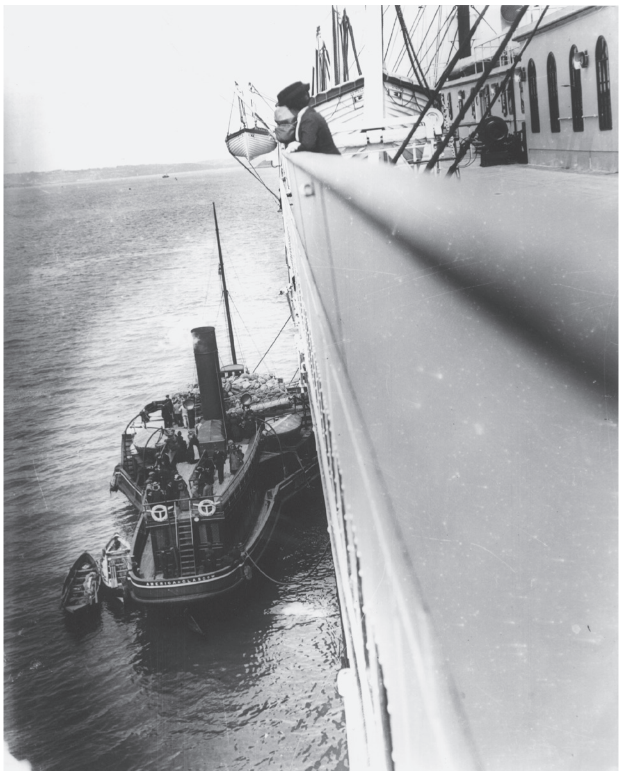


Fig. 21-37 **Loading Mail from Tender** – Mail is handled on *Titanic*'s port side at Queenstown by the tender America. *(Cork Examiner photograph/Campbell McCutcheon Collection)*

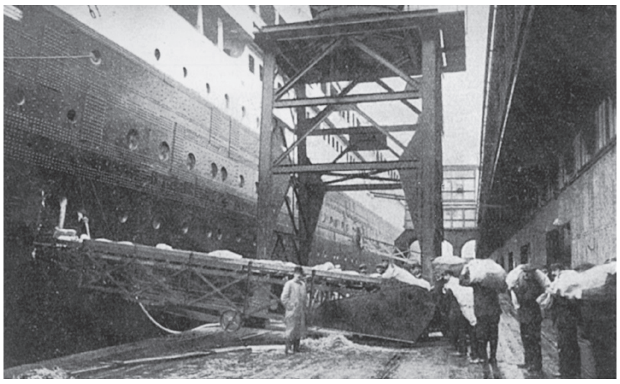


Fig. 21-40 ***Olympic* Loading Mail** – Mail being taken aboard the *Olympic* from the White Star Dock at Southampton. *(*Railway and Travel*/Daniel Klistorner Collection)*

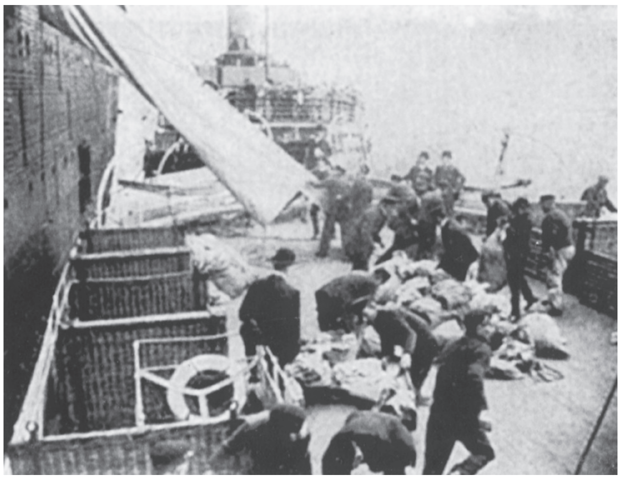


Fig. 21-38 **Mailbags on *Mauretania*** – Mailbags being offloaded onto a tender from the *Mauretania*. *(*Railway and Travel Monthly*/Daniel Klistorner collection)*

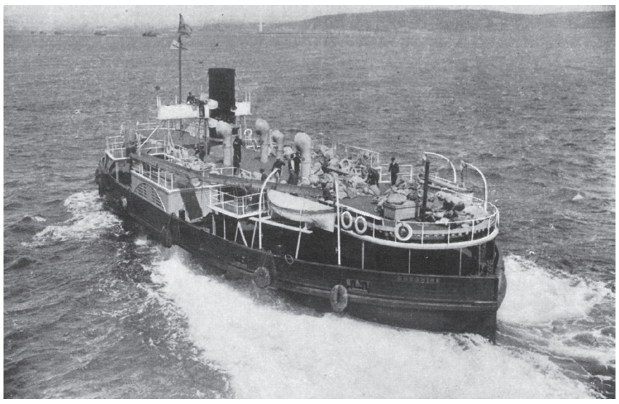
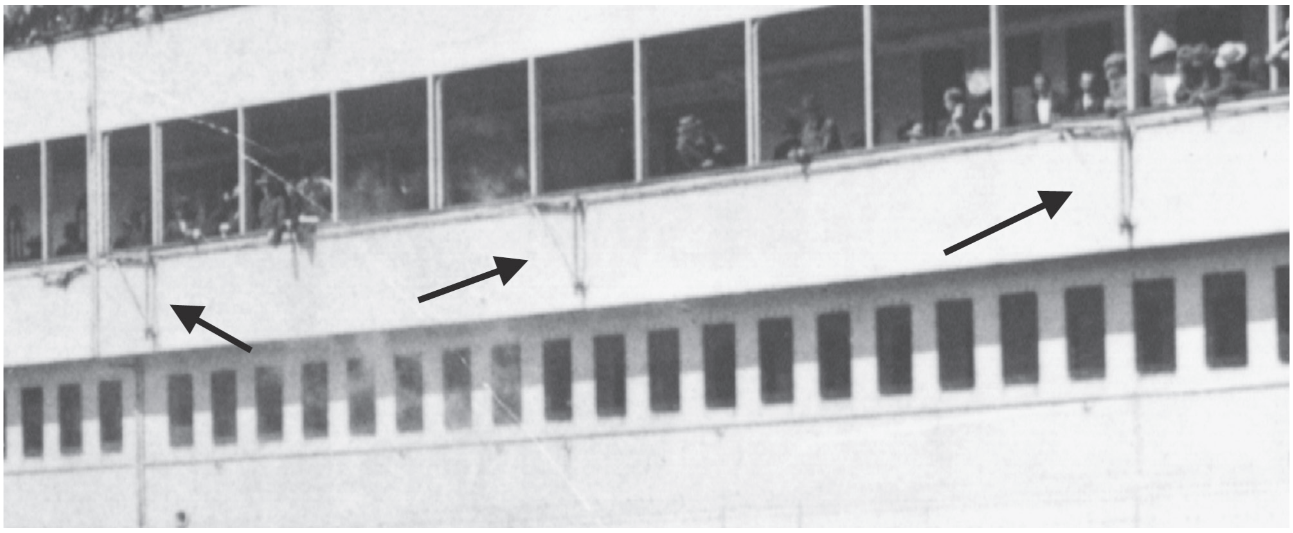


Fig. 21-39 **Mail Aboard Tender –** Mail aboard the tender *Cheshire* in Plymouth Harbor. Plymouth was a port of call on the return leg of *Olympic*'s transatlantic voyages, and would have been for *Titanic* as well. *(J. Kent Layton collection)*

Below Fig. 21-41 **Coaling Outriggers** – In this image of *Olympic*, three of the coaling outriggers are indicated with arrows.



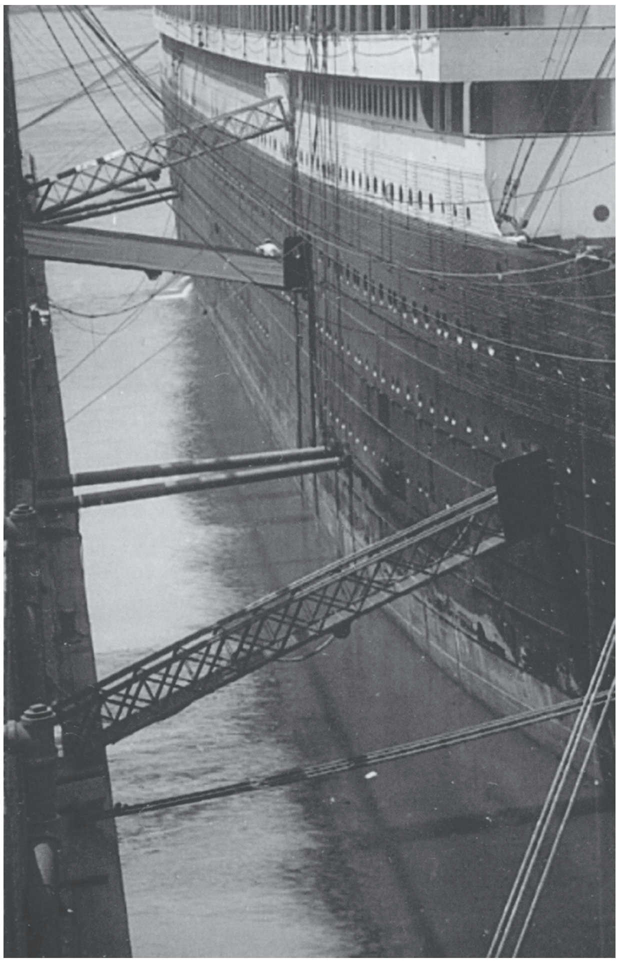


Fig. 21-42 **Ship Boomed Out From Dock** – *Olympic*, seen here at New York in 1911. The ship is boomed out away from the pier in order to allow for the coaling barges to pass between. The line of coaling outriggers can be seen at the top of the superstructure along the A Deck bulwark. *(Josha Inglis collection)*

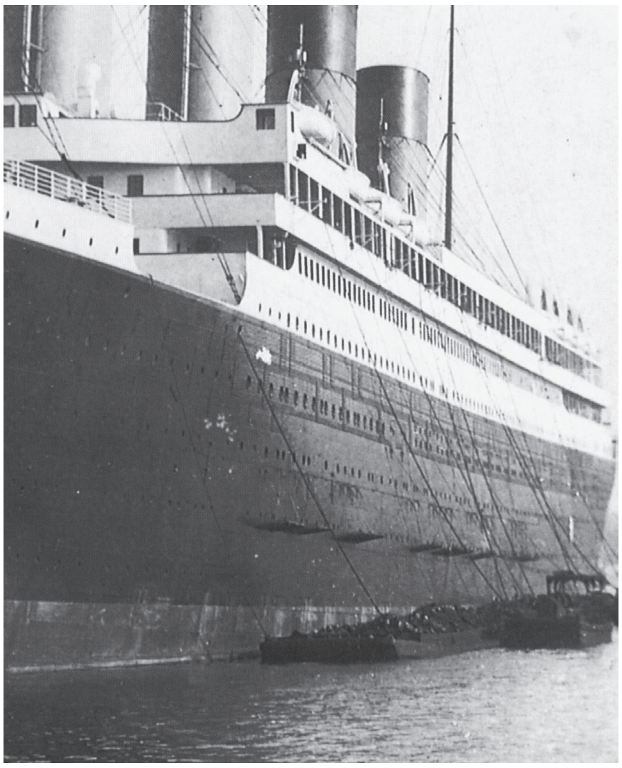
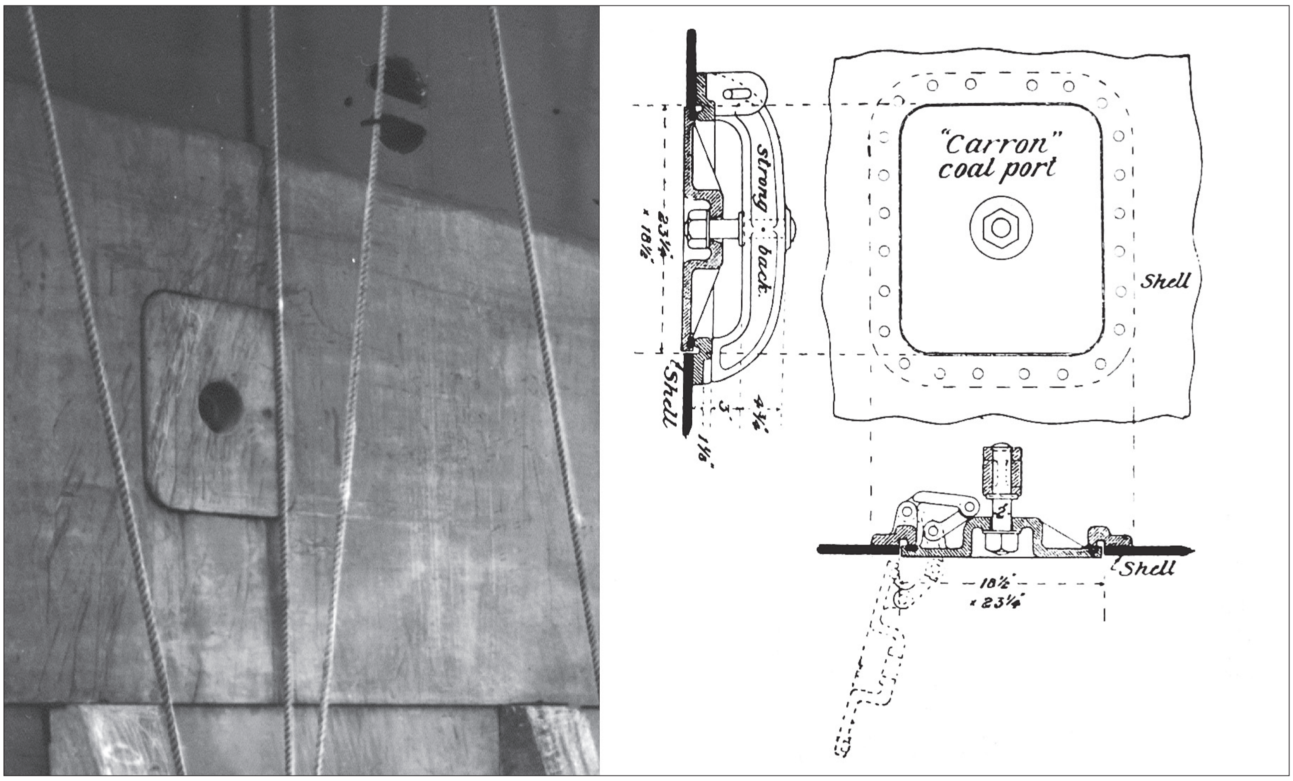


Fig. 21-43 ***Olympic* Ready For Coaling** – *Olympic* being coaled in 1911. The outriggers are swung out, the barges are alongside and the coal handling platforms are in place. *(Ray Lepien collection)*

Below Fig. 21-44 **Coaling Port** – At left, a closeup of one of *Olympic*'s coaling ports, and at right, a diagram of one of similar design. *(Left image from authors' collection; right image from* Practical Shipbuilding*)*



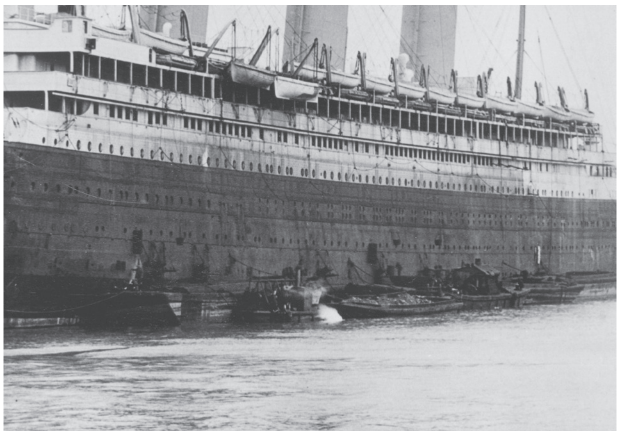


Fig. 21-45 ***Olympic* Coaling** – *Olympic* being coaled early in the First World War. Note how dirty the ship is here; outside of wartime service her appearance would never have been allowed to deteriorate like this. *(Ray Lepien collection)*

coke stores for the D Deck galley, but also to secure scaffolding, bosun's chairs and other devices for general maintenance use.

Coal was supplied at Southampton by the firm of R. & J. H. Rea. The ship was boomed about 20ft out from the dock with timbers so the coal barges, or lighters, could be positioned adjacent the coaling doors along both sides of the hull. The coaling doors, or coaling ports, opened into coal chutes[3] in the ship's hull, just below the Middle Deck (F). The coal chutes, in turn, led to upper levels of the coal bunkers themselves. In order that the coaling operation would not interfere with the passenger accommodations internally, the chutes were contained within trunks that angled down from the side of the ship inboard to the coal bunkers. The exterior coaling doors (18 port and 17 starboard) were of the cast-steel flush type, and covered a clear opening of 2ft 0in x 1ft 9in. The hinges were of a type that allowed the door to swing completely out and free of the opening.

When all was in readiness for coaling, the 'coalies' on the lighters would shovel the coal into large buckets rigged to lines, or whips, rove through gin blocks attached to the outriggers swung out above. Using this rigging, the buckets were hoisted to workers crouching on platforms rigged below the coaling ports. To facilitate loading, the ports were supplied with fittings to take a temporary sheet-iron scoop. The workers on the platforms then tipped the buckets to dump the coal down the chutes, which lead down into the 'tween deck spaces between the F and G Deck levels along both sides of the ship; from there it was then transferred into the coal bunkers. The bunkers were all arranged transversely and positioned amidships so that in the course of a voyage the consumption of coal would not greatly affect the trim of the vessel as the bunkers were emptied out.[4]

In ship design, the size of the coalbunkers depended on the class and use of the vessel. Because *Titanic* was an ocean liner, designed to follow generally one route, Harland & Wolff could accurately calculate the consumption of coal that would be consumed. The fact that Welsh coal was used also entered into the size of the coal bunkers. Unlike coal mined elsewhere in Great Britain which was largely bituminous coal, Welsh coal – which was semi-bituminous, and much harder with a higher carbon content – was the preferred type for marine use as it burned hotter, cleaner, and produced less smoke. From the point of view of both the engineer and shipbuilder, Welsh coal was a more efficient source of heat, and therefore not as much needed to be carried as with other types.

After coaling, the Carpenter would seal up the coal ports with a buckram gasket soaked in red lead. The doors were hove tight by the use of a single bolt through the center which tightened an internal dog or 'strong-back' bracket which sealed the door against the shell plating, creating a watertight seal.

Loading four to five thousand tons of coal took a minimum of twenty-four hours to complete and was a filthy, exhausting, and backbreaking job for those involved. This was only the beginning of work for the crew, however: invariably, the coaling process had deposited a fine film of coal dust all over the exterior of the ship. During the entire process, to prevent coal dust from entering the ship the majority of the ship's ventilation systems were shut down and any open ports and ventilators were sealed. This, however, was never fully effective, and a light film of the black dust still managed to find its way into the interior of the ship, requiring the crew to clean the entire ship after every coaling procedure.

Notes

1. As expressed here, cargo capacities in gross tons actually refer to volume rather than weight. One gross ton is equal to 100 cubic ft of cargo space.
2. It will be recalled that 'cwt' is an abbreviation for 'hundredweight,' or 112lb. Thus a 50cwt crane could lift 5,600lb, and a 30cwt crane could lift 3,360lb.
3. The 1912 spelling of 'chutes' was 'shoots.'
4. It should be noted that in circumstances of special necessity, the No.3 Hold – also called the 'Bunker Hold' – could be utilized for the stowage of coal. As the name indicated, it was loaded through the No.3 Hatch on the forward Well Deck.

Chapter 22

Navigational Equipment, Steering, Telegraphs, Flags and Signaling Equipment

NAVIGATIONAL EQUIPMENT

The term 'navigational equipment' for the purposes of this writing will include compasses and other devices for taking bearings, sounding instruments, logs, navigational maps, navigational lights, steering of the ship, communication and signaling, etc.

Binnacle

A binnacle is a protective housing for a compass on a ship.[1] Over time, they ceased to be just wooden cupboards, and were constructed as wooden stands to hold the compass in a fixed position in view of the helmsman at the wheel. When iron came to be used for shipbuilding it was important to protect the compass from its influence, so binnacles were increasingly designed to include measures to reduce or eliminate compass deviation. In the nineteenth century, when ships were being made completely of iron, the binnacle was to become an all-brass fixture surrounding the compass, with a protective, non-ferrous coat.

William Thompson (1824–1907), a Scottish physicist,[2] devised in the late 1870s a patent compass and binnacle that completely revolutionized the device. It was the first to successfully incorporate all the requirements for an accurate instrument in one model, and was the basis for subsequent binnacle-compasses. It was simple in design, having a mahogany or teak box, a brass cover, brackets for oil lamps, and – most important – cells containing magnets to counter the deviation of the compass caused by the iron hull of the ship.

Titanic's binnacle on the Navigating Bridge[3] was located at the centerline forward. It was a 10in-diameter Kelvin-White compass in a teak binnacle standing about 50in above the deck level, the binnacle being 15in in diameter.

The magnetic compass

Titanic was fitted with four main compasses. One steering compass was located in the Wheelhouse and another in the Navigating Bridge, a third on the elevated Compass Platform on the raised roof over the First Class Lounge and a fourth located on the Docking Bridge aft. Following are their specifications:

One Lord Kelvin's 10in latest Patent Standard compass with azimuth mirror on the Compass Platform.
One Lord Kelvin's 10in latest Patent Steering compass complete for inside of Wheelhouse to suit the wheel pedestal shaft to the telemotor.
One Lord Kelvin's 10in latest Patent Steering compass complete for Navigating Bridge.
One Lord Kelvin's 10in light card compass on wood stand complete for Docking Bridge.
One spare card in box to suit Lord Kelvin's compasses.

All of the ship's compasses were lighted with electric or oil lamps, and the Docking Bridge compass was fitted with a lighted card. They were adjusted by the firm of C.J. Smith of Southampton.

Compasses had been in use for hundreds of years, but care had to be taken not to bring any metal objects in proximity to the compass as such materials created havoc on accurate navigation due to their magnetic influence. With wood-hulled sailing ships this presented no major problems, as the amount of iron on any given ship was negligible. When iron-hulled ships became the norm, however, this problem finally had to be solved – in fact, apart from the mass of iron in the ship itself, even the hammering of the rivets while the ship was being built caused the hull to have its own magnetism that affected the compass.

Compasses aboard ships were subject to two types of error, variation and deviation. The former resulted from the influence of the magnetic North Pole as it attracted the North point of the compass away from the true North on which all maps and charts were based. Variation is easily dealt with in navigation, as the location of the magnetic North

LORD KELVIN

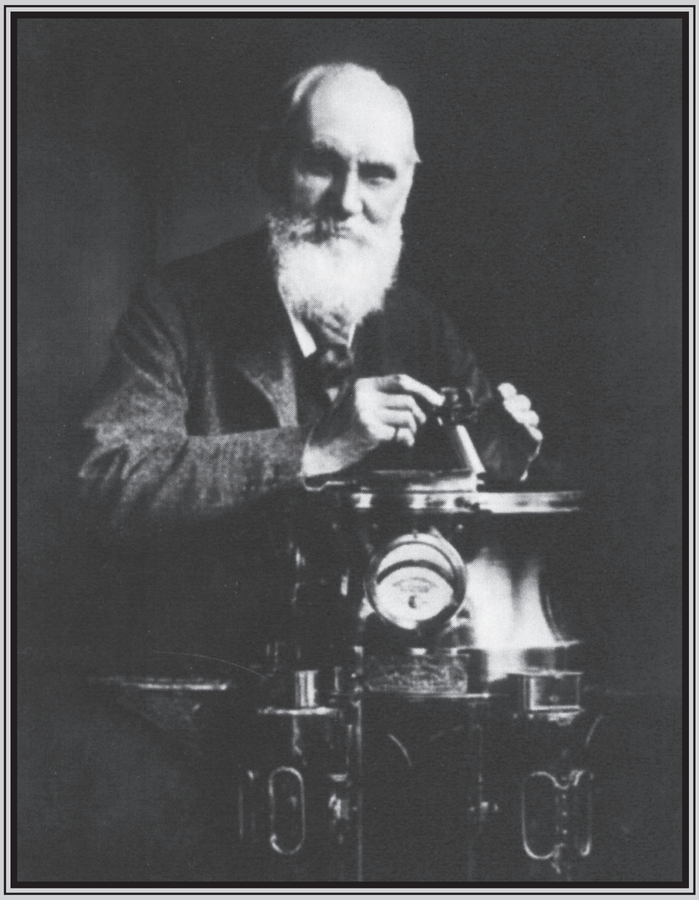
No chapter on navigation would be complete without giving recognition to Lord Kelvin (1824–1907), an accomplished electrical engineer and pioneer in the field of submarine cable signaling apparatuses, navigation and electrical instruments. Born in Belfast as William Thompson, this Scottish physicist, mathematician and engineer was knighted in 1866 for his research into the transmission of electric currents in submarine cables that led to the success of the great Atlantic cable; he was created a peer in 1892 for that and much other important work, including what he did for the mariner's compass. He invented sounding apparatus and a tide-predicting machine as a result of his remarkable research work in hydrodynamics, particularly wave motion; not only his adopted home town of Glasgow but also the entire world owe a great deal to him.

Lord Kelvin formed a working relationship with the Glasgow instrument-maker James White, and together they produced and sold a new generation of precise electrical and other instruments patented by Lord Kelvin. The firm of Kelvin & James White Ltd, Glasgow and London, supplied *Titanic*'s compasses, binnacles, sounding machines and much more. Lord Kelvin subsequently accumulated great wealth through his patents and business interests and became a major shareholder in the company after White's death in 1894.

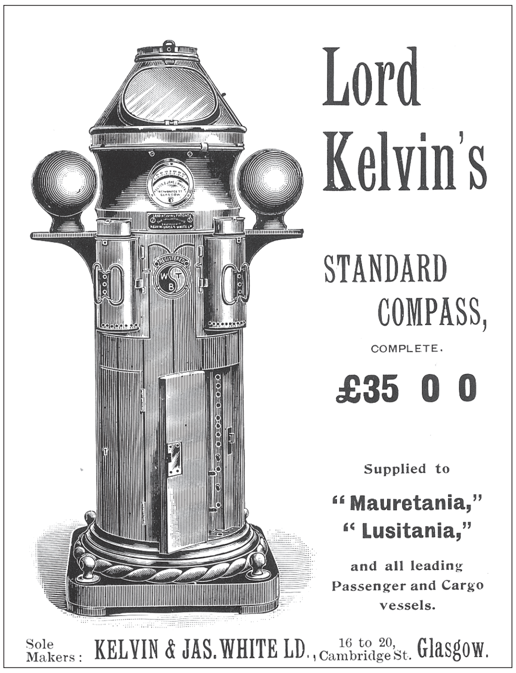
The introduction of ships with iron and steel hulls had resulted in significant errors in compass readings, so Kelvin developed a binnacle that compensated for the magnetism of the hull and superstructure of the ship. His company produced more than 10,000 binnacles for ships all over the world. The firm of Kelvin & James White Ltd was renamed Kelvin, Bottomley & Baird Ltd in 1914. The firm then merged with Henry Hughes & Son Ltd in 1947, becoming Kelvin & Hughes Ltd, which was acquired by Smith's Industries Ltd in 1964.

Lord Kelvin died in Glasgow in 1907. His ashes are interred in Westminster Abbey, near the grave of Sir Isaac Newton. A commemorative statue in the Botanic Gardens, Belfast, is inscribed:

He elucidated the laws of nature for the service of man.



Lord Kelvin – Lord Kelvin with one of his inventions. *(Private collection)*



Lord Kelvin's

STANDARD
COMPASS,
COMPLETE.

£35 0 0

Supplied to
"Mauretania,"
"Lusitania,"
and all leading
Passenger and Cargo
vessels.

Sole Makers: KELVIN & JAS. WHITE LD., 16 to 20, Cambridge St. Glasgow.

Fig. 22-1 **Kelvin Compass Advertisement –** This period advertisement for a Lord Kelvin's standard compass shows a binnacle very similar to the one raised from *Titanic*'s wreck. In the binnacle illustrated here, the oil lamps have been inserted into the slots below the brass compass cover. The open door at the base shows the cells for the compensating magnets. *(*The Shipbuilder*/Authors' collection)*

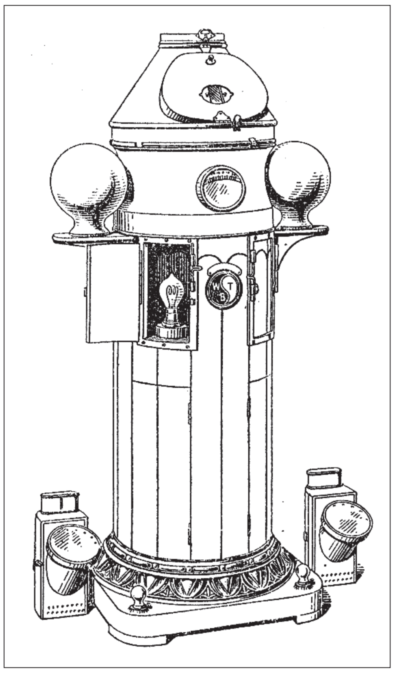


Fig. 22-2 **Binnacle of Kelvin Compass** – This illustration is unique in that it shows the position of the electric light bulbs in the binnacle. The oil lamp attachments are shown at the base of the device; these oil lamps had upward-angled lenses to illuminate the compass bowl from below.

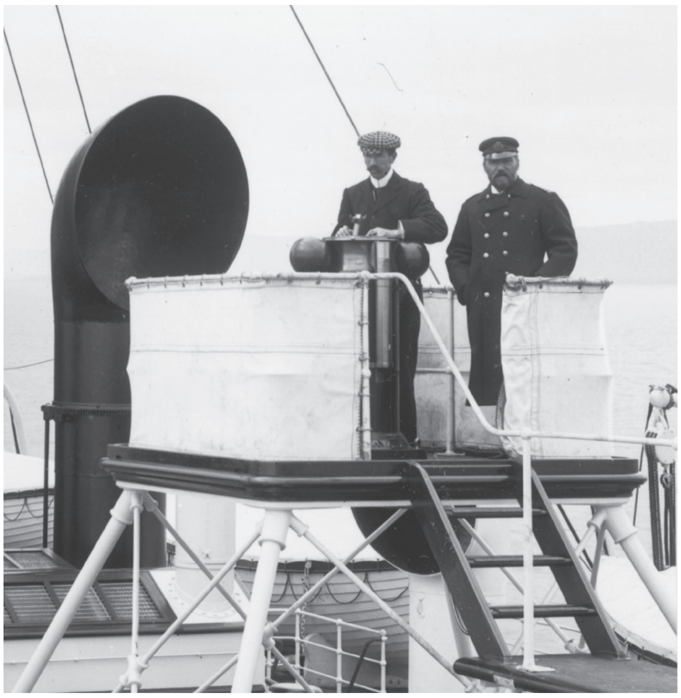


Fig. 22-3 **Adjusting Compass** – An officer and a compass adjuster aboard the Harland & Wolff-built *New England* of the Dominion Line *c.*1898. *(H&W/Authors' collection)*

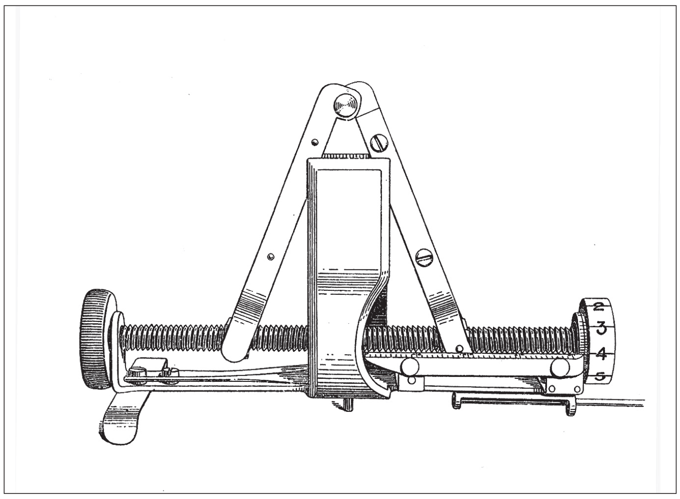


Fig. 22-4 **Kelvin Deflector** – Lord Kelvin's 'deflector' was a pair of magnets fixed to the ends of a pair of legs arranged somewhat like the legs of a pair of dividers. By opening the legs the magnets were caused to move further apart, and their power to deflect the compass needle was increased. This instrument was placed on the glass top of the compass bowl, and the legs were opened until some definite large angle of deflection was observed, for example 85°. Then it was removed; the ship's head was turned to another course, and the deflector was replaced. If the same opening of the legs just sufficed to give the same deflection on this second course, the directing field on both courses was the same. The process was repeated for other courses, and if differences were found the correcting magnets were adjusted until the differences were eliminated.

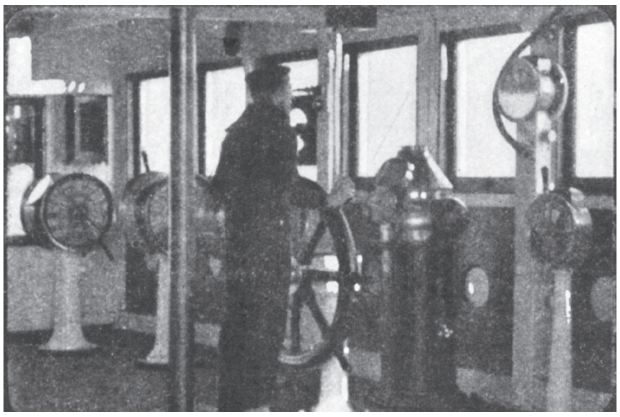


Fig. 22-5 **Navigating Bridge Binnacle** – The brass cover for *Olympic*'s binnacle from this 1920s-era promotional film can be seen right in front of the Quartermaster at the wheel. This would have been the same on *Titanic*. *(Ray Lepien collection)*

Pole is known, and the degree of variation can be accurately determined for any point on Earth. In compensating for variation, the ship's navigator simply adjusts his compass course as necessary according to the known variation for the area – for example, when *Titanic* cleared Fastnet Light on April 11 at the start of her transatlantic course track for New York, the local variation was 19° 59 minutes. In other words, there was nearly a 20° compass error at that location on Earth. To compensate for this, the Quartermaster at the wheel would have had to hold a compass course about 20° different from the true course.

The second type of compass error was deviation, caused by the magnetic influence of iron in the ship and in proximity to the compass, and, as noted, the magnetism created by the riveting process. Deviation was much more troublesome, and could not be simply 'calculated away'. However, deviation could effectively be countered, or largely neutralized.

Magnetic compensation

Even a small piece of iron left next to a magnetic compass could strand a ship. Iron or steel, even in masses as small as a pocketknife, if brought near the compass, could affect it, and helmsmen and quartermasters understood this. Moreover, as far as practicable, magnetic compasses were to be positioned away from steel or iron as much as possible within the confines of a steel-hulled ship. The roofs and bulkheads of *Titanic*'s Navigating Bridge shelter and Wheelhouse were made of wood to satisfy these requirements.[4] Stanchions, railings and other metal fittings near a compass were preferably made of bronze or other non-magnetic substance. If made of iron, they were not supposed to ever be removed from their usual positions while the compass was in use.

Matthew Flinders (1774–1814), an explorer and navigator, had conducted experiments between 1800

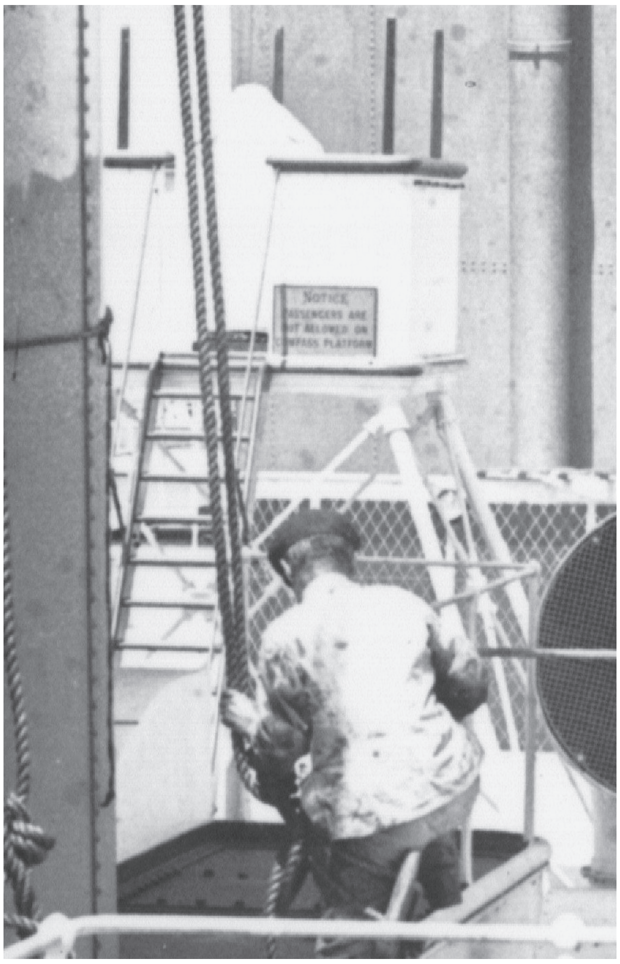


Fig. 22-6 *Compass Platform Binnacle* – In this 1911 image from *Olympic*, the Compass Platform is visible in the background. The binnacle in the center of the platform has been covered with its protective canvas. Also visible here is the sign warning passengers to stay off the platform.

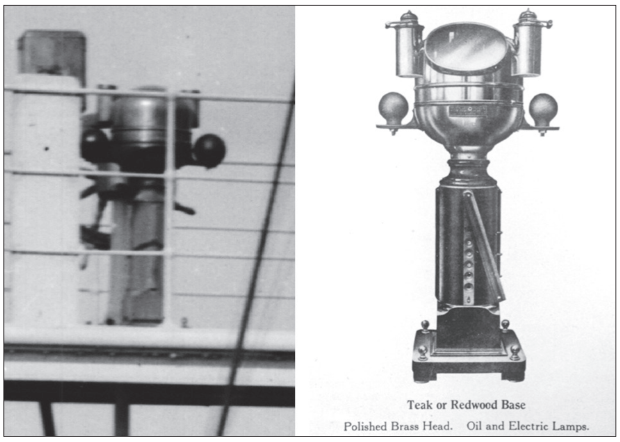


Fig. 22-7 **Docking Bridge Binnacle** – At left, a view of the binnacle on *Olympic*'s Docking Bridge. At right, a period Kelvin & James White Ltd advertisement showing the type used on the *Olympic*-class ships. Termed a 'Pillar Binnacle for Steering Positions,' this type could be fitted for both oil and electric lighting, with the electric light fitted under the compass bowl.

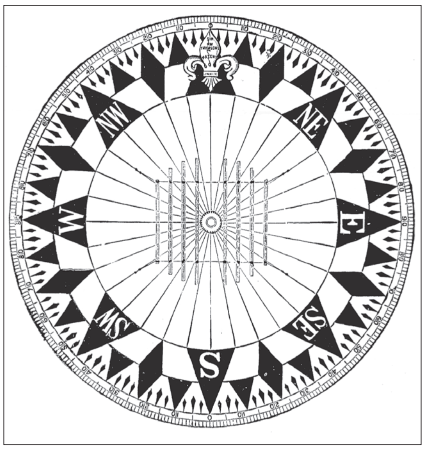


Fig. 22-8 **Compass Card** – An example of a Kelvin compass card from *Titanic*'s era. The lines drawn in the center represent the suspension threads.

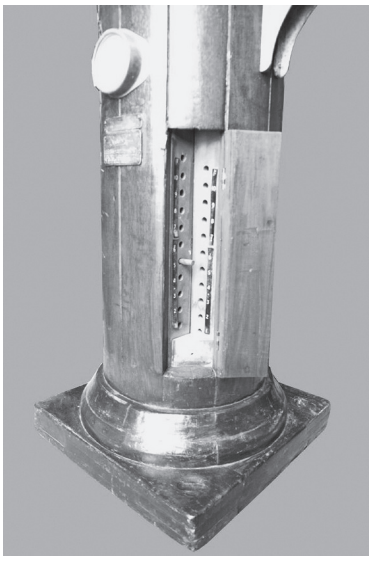


Fig. 22-9 **Bar Compartment** – A typical binnacle showing the compartment with holes or 'cells' for stowing the horizontal compensation bars.

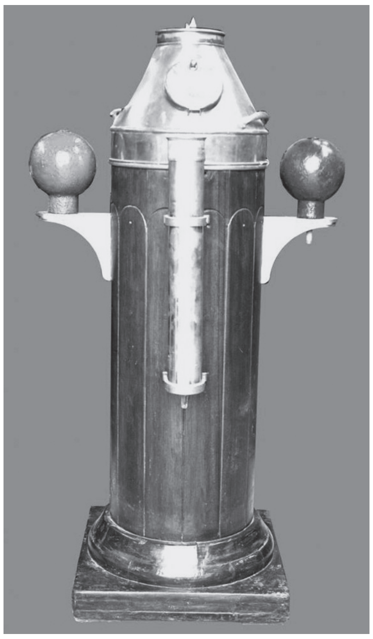


Fig. 22-10 **Flinders Tube** – A binnacle fitted with a Flinders tube. It is seen here in the center of the binnacle, mounted vertically.

and 1803 proving that if magnets and iron bars were placed in strategic positions in relation to the compass, then the deviation of the needle could be corrected. His 'Flinders bars' did effectively solve the problem, and his method was later adopted in the magnificent work of William Thompson. Thompson's compass of 1876 used eight lightweight needles attached to threads of silk. The threads radiated from a pivot with a sapphire cap to the rim of the compass. The use of several needles solved the problem of moments of inertia. Thomson's compass was much more sensitive than the regulation naval version of the nineteenth century, thanks to the fact that the all the internal components were much lighter in weight. The card in the Admiralty compass weighed 1,525 grains, while Thompson's was only 180 grains. His needles were shorter; and Thompson's compass on its rigid platform, with its sprung-gimbal suspension, was so successful that it remained in use well into the twentieth century.

On the forward side of the Kelvin binnacle was a brass cylinder, or 'Flinders tube', which would hold the vertical magnets called 'Flinders bars'. These were used to correct the deviation brought on by iron on the ship in a vertical plane. In the Kelvin compass, 3in-diameter Flinders bars of malleable iron were supplied, each 'bar' consisting of various shorter lengths. A full bar, 24in

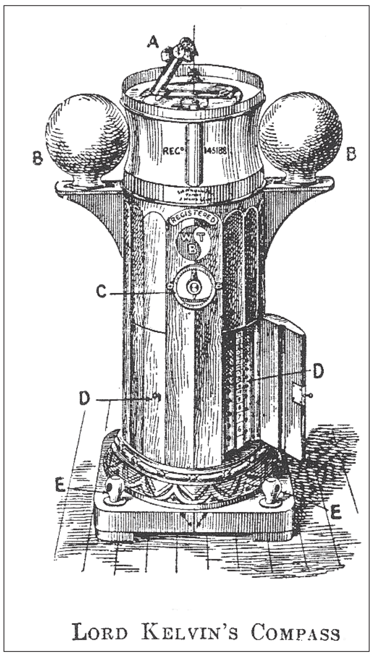


Fig. 22-11 **Lord Kelvin's Compass.**
A – Azimuth vane or mirror, the purpose of which was to take bearings. It rested on a pivot over the compass bowl, on top of the glass. It turned freely in all directions and was fitted with a prism which reflected an object in to the eye of the observer, and with a magnifying glass by which to read the bearings in degrees on the edge of the compass card. The shadow pin which is upright in the center was sometimes useful in taking bearings of the sun.
B – Soft iron spheres, which rested on brackets fitted to the compass for the purpose of correcting the quadrantial deviation.
C – Clinometer, showing the heel of the ship.
D – Magnets, placed athwartships and fore-and-aft in horizontal holes so that they could be raised or lowered and locked up. Their object, together with the Flinders bar (made up of segments of soft iron, and contained in a brass cylindrical base placed in a vertical position on the forward part of the binnacle), was to correct the semicircular deviation. A brass can, placed under the center of the compass bowl, contained a magnet for correcting the heeling error; the attached chain enabled its distance from the needles to be regulated.
E – Screws, which secured the binnacle to the deck.

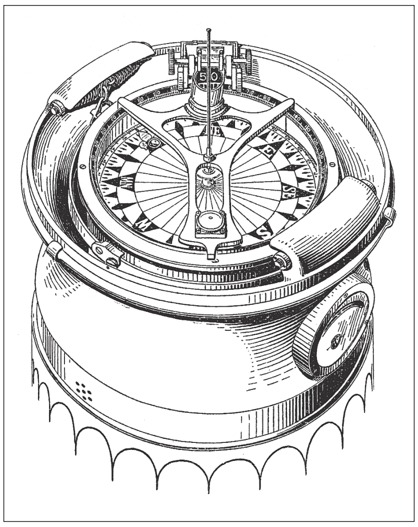


Fig. 22-12 **Kelvin Compass with Azimuth Mirror** – As an adjunct to the compass he invented, Lord Kelvin also invented the azimuth mirror, an apparatus which, fitted on the top of the bowl, allowed the bearings of distant objects to be readily taken.

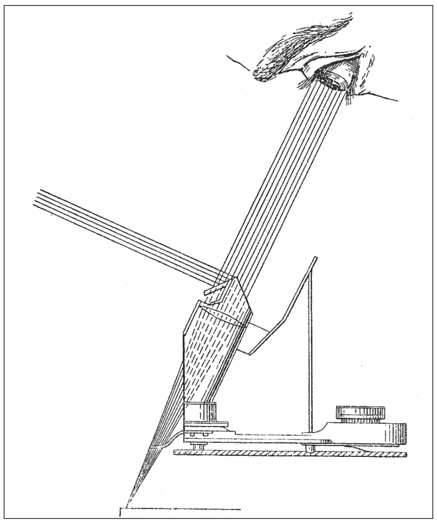


Fig. 22-13 **Azimuth Mirror** – This image illustrates the use of the azimuth mirror.

in length, consisted of one 12in-, one 6in-, one 3in-, one 1½in- and two ¾in-sections, and were generally contained in a traveling box. Pieces of wood of the same length and diameter were supplied in the brass tube attached to each Kelvin binnacle. Whenever the length of iron bar required had been taken from the box, the equivalent length of wood from the tube was to take its place, the remaining lengths of wood in the tube being necessary to support the iron bar in its proper position at the top of the tube. The tube itself was 24in in height and approximately 4in in diameter. The binnacle also had horizontal holes or cells bored within the stand into which compensating magnets were fitted.

The most noticeable fittings on the binnacle were two hollow, soft iron spheres permanently mounted on each side. The port sphere was painted red and the starboard green. These were mounted so as to slide in and out horizontally on their mounts, compensating for the deviations brought on by soft iron on the ship located in a horizontal plane. As this error was called 'quadrantial deviation', the spheres were termed 'quadrantial spheres'.

To accommodate heeling error, the Kelvin binnacle was fitted to receive a small steel magnet placed vertically below the center of the compass within the wooden binnacle. As with the two other forms of deviation correctors, this device was adjusted to keep the compass in check with the rolling and pitching of the ship. Each binnacle was also fitted with a small spirit clinometer on its forward side. This was used to check the compass for accuracy while on land after it was mounted within the binnacle, but before it was fitted on board ship.

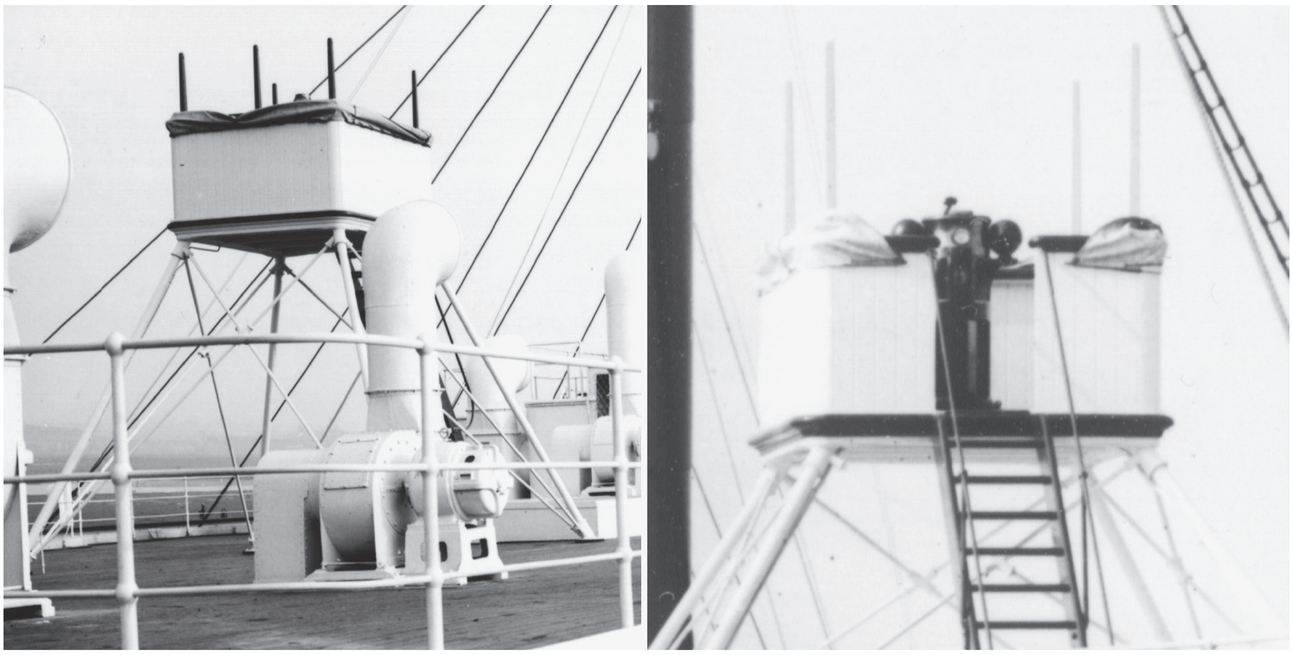


Fig. 22-14 **Compass Platform** – At left, the Compass Platform on *Olympic* as seen from ahead. Notice the four teak stanchions and the canvas folded around them at the top of the bulwark. At right, a similar compass platform on the Baltic *c.*1904. *(H&W/Authors' collection)*

As a result of all the above measures, the local influences that unavoidably existed on steel ships were neutralized to a large degree. The compass needle did, ultimately, point more or less (within a few degrees) to the magnetic North Pole. Nonetheless, some deviation remained, and for this reason it was still desirable to have a 'standard compass' on the ship by which the accuracy of the other compasses could be checked. Somewhere on every ship there was a spot practically free from magnetic influence of the iron on the ship, or, more accurately stated, a location where the various surrounding forces of magnetism would neutralize each other or become so evenly balanced there that a compass mounted at that location would be almost, if not altogether, free from deviation. This 'neutral spot' on *Titanic* was almost amidships, over the raised roof of the First Class Lounge. At this location a raised Compass Platform was constructed, built of galvanized iron, brass work and wood. The platform stood 12ft above all ironwork on the Boat Deck and stood 78ft above the water line. There were four stanchions mounted on the bulwarks of the platform to take canvas for protection against inclement weather. The platform and support legs were painted white with a brown nosing around the margin board. The compass in this location was also fitted with an 'azimuth mirror', a device used to take bearings of celestial bodies to plot the ship's position.

Compass card

The essential part of a compass is a magnetic needle which turns freely on a pivot and which, if unaffected by local disturbing influences, will point due north and south. Attached to the needle, and moving with it, was a circular card marked around its circumference with 32 points. This marking system predated steam-powered ships by hundreds of years. The cards were divided into thirty-two points; these included the main four cardinal points of North, South, East and West, and the intercardinal points of Northeast, Southeast, Southwest, and Northwest. These eight points were further divided into twenty-four smaller points, giving directions such as 'East–Southeast', and 'Southwest by South' etc. Thus, when a bearing was given with the old compass cards one would hear directions indicated such as 'North–Northeast' or 'South–Southwest a half West', no degrees being utilized. Naval midshipmen and other students of navigation were expected to be able to 'box the compass' early on in their careers by naming all thirty-two points in order.

The card with the attached needle was floated in a chamber filled with a liquid composed of 45 per cent pure alcohol and 55 per cent distilled water. It pivoted upon a jeweled bearing which kept the card centered and supported a small fraction of its weight. On the inside rim of the card chamber was a vertical mark known as the 'lubber's point' or 'lubber's line' which was carefully adjusted to the fore-and-aft line of the ship with reference to the center of the card. In steering, this mark was held in line with the point of the card indicating the course to be steered.

As there are 360 degrees in a circle, it will readily be appreciated that the thirty-two points on the old mariner's compass card did not readily equate to an even number of degrees. Of the thirty-two points, each point represented 11¼ degrees, or 11 degrees and fifteen minutes (11° 15') of arc. Because there were eight points between North and East representing one-quarter or 90° of a circle, each point equated to 11¼°. The compass cards used on *Titanic* were of a newer design in that they indicated degrees along with the old standard of the points and fractional parts of points. The accuracy with which steamers could be steered by degrees eventually led to the disuse of the points and quarter points, as the seemingly trifling error that was involved in attempting to steer by fractions of a point – while of little consequence to a slow vessel in a short run – could eventually result in a large aggregate error to a steamer making four or five hundred miles a day.

The graduation by degrees on a magnetic compass card began at North and at South, each of which corresponded to zero, and ran 90° to the right and left toward East and West, respectively. These bearings signified latitude, and all directions were given from North or South first. Thus, the card had, in the Northeast quadrant, N 1° E, N 2° E, etc., up to N 90° E; and in the Southeast quadrant, S 1° E, S 2° E, etc., up to 90° E. East could be regarded, therefore, as either N 90° E or S 90° E, although in practice would have been called 'due East'. Because the compass card indicated both degrees and the old mariners points, the courses could be designated in either way. Northeast was N 45° E; East–Southeast was S 67° 30' E; Southwest by South was S 33° 45' W; etc.

Courses and headings

There were three methods by which courses or headings could be expressed on ship – true, magnetic, and compass – and it was always important to distinguish between them. 'True' referred to the geographical North Pole, the direction of which was indicated on the charts. The true course was the heading (direction) the ship would follow if based only on true North, and does not take magnetic deviation or variation into account. A 'magnetic' course, sometimes called a 'standard' course, is corrected to allow for the variation error caused by the attraction of the compass needle to the magnetic North Pole rather than the true North Pole. The magnetic course differs from the true course by the amount of variation at that point on the Earth. Harbor pilots were known for using magnetic courses (and often gave their orders in the old quarter points), as over the relatively short distances involved in piloting a ship, no appreciable errors in navigation would result. However, a ship could not follow a magnetic course over great distances, because it did not allow for any remaining deviation error caused by the iron of the ship and its own magnetic field. While the compensating mechanisms of the binnacle greatly reduced the deviation error, it could not be eliminated completely, and for this reason the amount of deviation for the steering compasses were regularly checked and recorded. The amount of deviation, if any, was then factored in when a determining the 'steering' or 'compass' course that the helmsman would actually follow. Stated another way, the steering course was corrected for both deviation and variation, and was the course that would need to be steered in order to keep the ship on its intended course. This was the course that was handed over from one Senior Officer to another at change of watch.

At sea, steering by compass required the Quartermaster at the wheel to keep the lubber's point of the steering compass (the lubber's point indicating the direction of the ship's head) on that mark of the compass card. If the ship was on a course of N 45° E, and the officer of the watch called a change of course to N 40° E, the Quartermaster had to swing the ship's head 5° until the lubber line was on the 'N 40° E' mark on the compass card. The binnacle for the steering compass located in the Wheelhouse was designed with a fitting in the center of the wooden stand to allow the shaft coming from the wheel to pass directly through the binnacle to the telemotor. This type of compass enabled the Quartermaster to see the direction of turn as well as the heading compared to magnetic North.

Periodically, the course being steered had to be checked against the standard course. On *Titanic*, the method of doing this consisted of a Junior Officer going to the elevated Compass Platform on the Boat Deck. Communication between the Compass Platform and the Wheelhouse was achieved with a bell push. When the ship was on her course by standard compass he would ring the bell continually indicating such. Then the Senior Officer of the watch inside the Wheelhouse compared it to the compass the Quartermaster was steering by. The officer would then record both the standard (magnetic) course and steering course, which usually varied by 2 or 3°. The course was then indicated on a 'course board' located in close proximity of the binnacle right in front of the Quartermaster. Therefore, the Quartermaster knew at all times the difference between the two compasses and could compensate his steering by the information provided on the board. During his assigned watch, the Quartermaster was also required to report the course to the Junior Officer in the Wheelhouse every quarter hour, or whenever required to make sure the ship was always on the right heading. On the night of the sinking the true course was reported as being S 86° W (86° west of South) and the magnetic course about N 73° W (73° west of North). The steering course was N 71° W, a variation of 23° from the true course to what the Quartermaster was required to keep the ship's head on.[5]

Deviation cards were kept aboard ship and dated for the day on which the deviations were found. However, these could not be relied on after some time elapsed, especially when the ship had materially changed her latitude or taken in cargo consisting of iron. A more up-to-date and reliable plan was to keep a regular record of the deviations of each compass, in which entries were duly made whenever trustworthy observations for compass errors were obtained. Such a record was exceedingly useful for showing at a glance the changes that were continually going on in the magnetic character of the ship and affecting the compass; and it was indispensable at times when new observations could not be had owing to weather conditions, etc. Each watch officer was to ascertain the compass deviation whenever opportunity offered, and if these agreed tolerably, the navigating officer, subject to the Captain's approval, would make such new entries into the log.

Navigation and position plotting[6]

The landsman with a limited knowledge of navigation often assumes that a ship's position at sea is determined by 'shooting the sun' with a sextant. While this method was used during daylight hours, the position of the sun by itself would not yield a position of any great accuracy. A single observation of any heavenly body (including the sun) yielded only a position line on which the ship was ostensibly located. Because of the need to triangulate a position based on a multiple number of heavenly bodies, the ship's position was not precisely known during the daylight hours. The only relatively accurate positions were obtained in the morning and evening by observing three or more stars and/or planets in quick succession. This was done when it was dark enough to see the stars but light enough to see the horizon. A position line was obtained from each celestial body and corrections applied to allow for the ship's movement between sights.

The ship's position was at the intersection of the three best lines or, if the lines did not all intersect at the same point on the chart, within the small triangle formed by their near intersection. A good position calculation was generally accurate to within a tenth of a mile.

Daylight navigation would start with a sun sight fairly early in the morning, when the sun had risen sufficiently above the horizon to be clear of serious refraction problems. The ship's longitude was then determined using a method known as 'longitude by chronometer'. This method was found to be accurate to within about a mile.

When the sun neared its zenith at local midday, the sextant was used to measure its maximum altitude and a simple calculation gave the latitude. If the conditions were right, the accuracy would be within less than a mile. 'Dead reckoning'[7] was then used to carry forward the morning longitude sight and cross it with the noon latitude. Dead reckoning was the process of calculating a ship's current position based on the direction and distance traveled from the last known or estimated position. The navigator also had to factor in the set and drift of any current over the time elapsed since the last position, as even a 1-knot current over a hundred miles could result in a significant error. Dead reckoning depended on accurate steering by a properly corrected compass, and the speed was normally estimated by propeller revolutions (based on trials over a known distance) along with a device called a 'log' that measured the vessel's speed through the water. The Walker's taffrail log (discussed later) was utilized on *Titanic*, but these instruments were known to show inaccuracies when being used on fast ships, and were generally not completely relied upon.

Dead reckoning gave the traditional noon position, and from this the day's run was calculated. Although much weight was given to the noon position, it was not all that accurate, as it depended on dead reckoning for the longitude. It was really a tradition from the days before chronometers, when the noon latitude was the only reasonably accurate sight obtainable.

Daylight navigation generally concluded with another longitude by chronometer in the afternoon. Sometimes extra sights were taken at times when known dangers were near or when a landfall was expected. In overcast weather, sights were taken whenever possible. Any position obtained was better than none, and a good sight in the morning would sometimes be carried forward later in the day, providing the officers a reasonably accurate position.

During the night the ship's position was estimated by dead reckoning, based on her speed and the course steered since the evening calculation. When accounts of voyages were given, such as seen on the log cards printed out for the passengers, it should be remembered that the distance run in a day was not necessarily over a period of twenty-four hours. This is because the time between noon positions varied according to the ship's change in longitude during the day as the ship moved east or west.

There was always a measure of inaccuracy in the ship's position. Even the morning and evening star sights only gave the position at the time they were taken, not at the time the calculations were completed (a fix with three stars could take up to an hour to calculate). However, good seamen were aware of the limitations of their methods and compensated for them.

The reported position of *Titanic*'s foundering was latitude 40° 46' N., longitude 50° 14' W. This position was determined not by celestial observations, but by dead reckoning. As history now records, this position was off by about thirteen-and-a-half miles, with the ship's actual position at the time of collision not as far along her course track as estimated. The reason for this error has never been conclusively determined.

Pelorus

Also known as a 'dumb compass', the pelorus was a circle marked with the graduations of a compass card, but without a needle. A pelorus could be used at any part of the ship for use in taking bearings. A 'bearing' is the direction of an object from the ship. It is measured in degrees, there being 360 degrees in a circle just as with a compass, the difference being that a bearing indicates the relative direction from the ship and not the compass

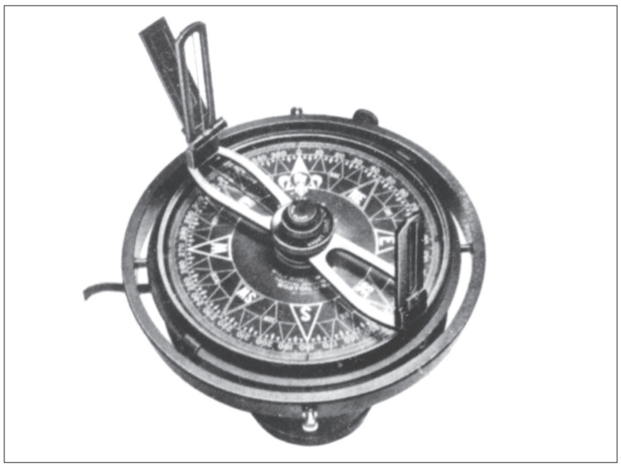


Fig. 22-15 **Pelorus** – A pelorus from a Kelvin & Wilfrid O. White catalog (US distributor) dating from sometime after 1912. The dial on the pelorus in this illustration is graduated in quarter points as well as degrees from 0 to 360. This type of compass graduation would not become standard until some years later, but the pelorus itself, as seen here with sighting vanes, would have been similar to what was used on *Titanic*.

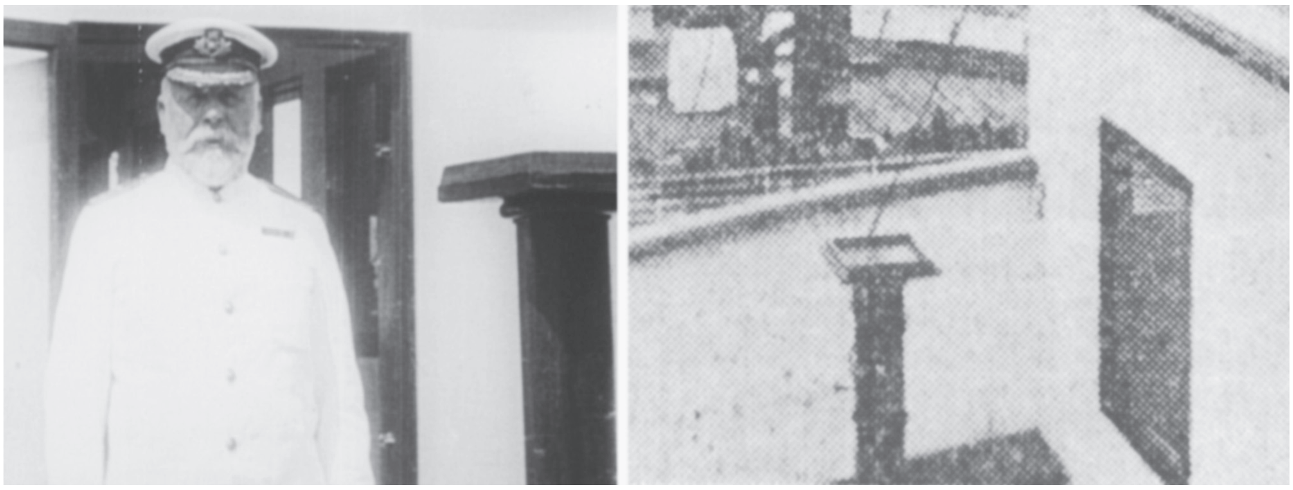


Fig. 22-16 **Pelorus Pedestal** – At left, in this image *c.*1911, Captain Smith stands next to the pelorus pedestal on *Olympic*'s starboard Bridge wing. At right, this image of *Titanic*'s port Bridge wing shows the matching pedestal on the opposite side. The window at the right of this image is the port-side window of the Navigating Bridge shelter. *(Both images authors' collection)*

direction. If a point of land was sighted directly abeam to starboard, it would be said to bear '090 (zero-nine-zero)' degrees. Bearings were typically taken when navigating in sight of land, using recognizable points of land, lighthouses and other features noted on charts. Just as celestial navigation relied on a series of position lines on which the ship was located, the intersection of which yielded the ship's position, so a series of bearings would yield the ship's position.[8] This was especially useful in navigating in channels or along the coast.

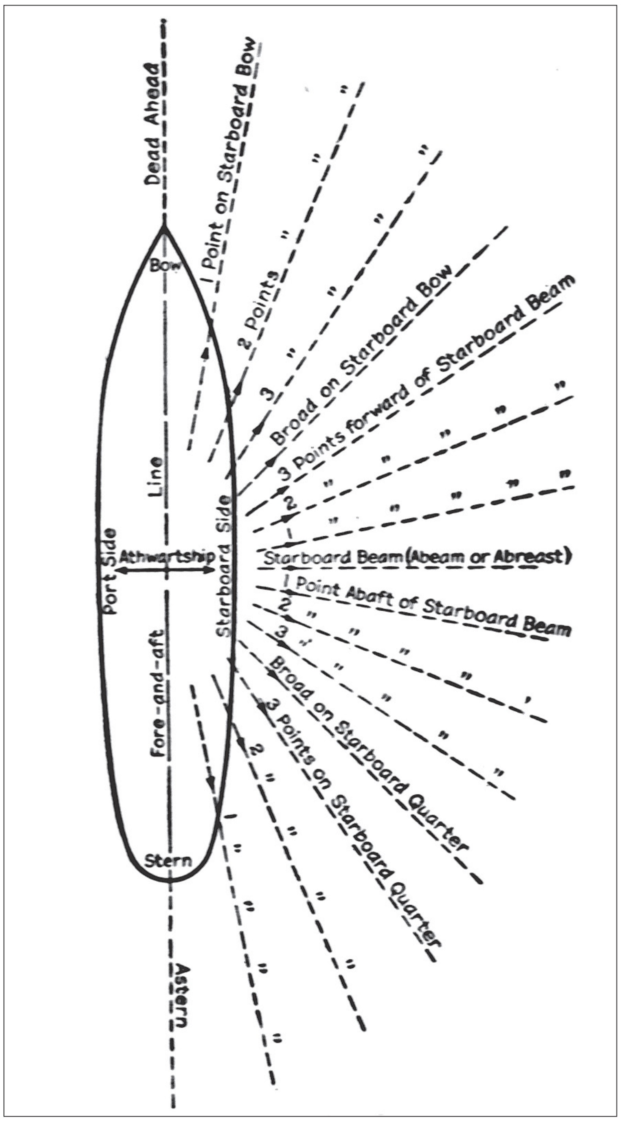

Dead Ahead
1 Point on Starboard Bow
2 Points
3
Broad on Starboard Bow
3 Points forward of Starboard Beam
2
1
Starboard Beam (Abeam or Abreast)
1 Point Abaft of Starboard Beam
2
3
Broad on Starboard Quarter
3 Points on Starboard Quarter
2
1
Astern
Bow
Line
Port Side
Athwartship
Starboard Side
Fore-and-aft
Stern

Fig. 22-17 **Relative Bearings** – In addition to the bearings obtained by use of the Pelorus, there was a second less-precise manner in which the bearings of objects or other vessels were reported as gauged by eye relative to the ship. In the system of relative bearings from the ship, the outer perimeter of the ship was considered as a circle divided into thirty-two sections or points, there being sixteen from ahead to astern on either side. This diagram illustrates the names of these points; these are the terms that would be used by a lookout, for example, in making a report to the Bridge.

On a pelorus, a zero-line was permanently fixed parallel to the fore-and-aft line of the ship, and a movable sighting bar permitted measuring the angle between the heading of the ship and the object being sighted. In this way the bearing was obtained. To determine the compass bearing of any object, the ship's heading by the compass and the bearing of the object by the pelorus were noted simultaneously. Bearings could thus be taken of objects which could not be seen from the compass. It must also be noted that the steering compass was not intended to be used for bearings, especially since its location inside the binnacle precluded sighting over it, except perhaps in the direction of the bow. The most convenient type of pelorus was one on which a graduated circle could be turned inside of the fixed rim that carried the zero-mark, while the sighting-bar turned independently of both. With this type of pelorus, the point of the movable circle corresponding with the compass course of the ship was made to coincide with the zero-mark, so that the compass bearings of objects sighted upon were read off directly, provided that the ship was exactly on her course at the instant of making the observation. If it was necessary to make the observation while the ship was not on the course for which the pelorus was set, the difference had to be noted and applied to the bearing observed.

The accuracy of the adjustment of the zero-line to the keel-line of the ship was determined by setting the circle to the compass course and taking simultaneous bearings of a distant object with the compass and pelorus. If an error was found, it was noted and applied as a permanent correction to all observations taken with the instrument. If the pelorus were set for the magnetic course instead of the compass course, the bearings observed with it would be magnetic.

Titanic had a pillar for a pelorus fitted on each side of the Navigating Bridge shelter port and starboard, directly outboard of the side windows. The purpose of the pillar on each side was to provide a base for the pelorus to raise it above the height of the forward bulwarks when the pelorus was in use.

Chronometer

The chronometer was a standard part of navigational equipment used aboard ship for calculating longitude. It was, in essence, a clock that kept track of time with great precision. A chronometer, moreover, had mechanisms incorporated into its movement to compensate for changes of temperature, humidity and other factors which would cause an ordinary timepiece to gain or lose time. The chronometer on British ships was kept by the Master and was used to record the time of celestial observations.

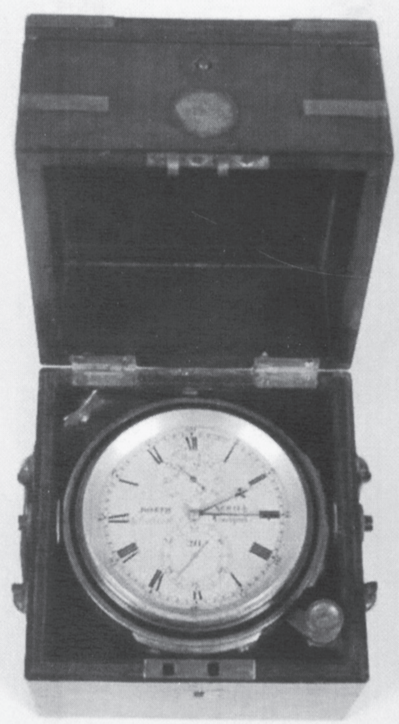


Fig. 22-18 **Chronometer** – Evidence from the chronometers of other White Star Line ships of the pre-First World War era indicate that the manufacturer of *Titanic*'s chronometer was likely J. Sewill of Liverpool. This image is of a two-day Sewill chronometer of the era. Chronometers were valuable instruments crucial to the ship's navigation, and were kept in protective cases.

The foremost problem of navigation for centuries had been how to find longtitude. There were simple tables to ascertain latitude, but not longitude. It was possible for a navigator to find his local time, but he was unable to determine his exact longitude because he did not know the time at the zero meridian.[9] (For many years the zero meridian varied according to the user's nation. By 1912, it was agreed to to be the meridian of the Royal Naval Observatory at Greenwich.)

Many inventors worked to create a device to overcome these problems, but it was not until the late 18th century that the first accurate chronometer was contained in a brass-bound mahogany box, with a lid on it that swung open so the time could be read through a glass pane. A key would be used to open a second lid that gave access to the mechanism, which swung on two sets of gimbals to maintain its level accurately in spite of the movement of the ship. By the 1830s most good ships had proper chronometers, although there remained mariners who preferred to obtain Greenwich Mean Time by observations of the moon relative to other celestial bodies (the Lunar Distance method).

The common chronometer was wound every twenty-four hours, though most could run for five days. They were never reset by physically moving the hands. If a chronometer ran down, it was not restarted until the time indicated on the dial was exact with Greenwich Mean Time (GMT). *Titanic* was fitted with two chronometers, a useful arrangement in case one of them became irregular. The chronometers were kept in a special cabinet in the Chart Room. While in port the chronometers were removed and sent to an optician[10] such as the Kelvin Company for calibration. The supplier of these expensive timepieces for *Titanic* is unknown; however, the firm of J. Sewill manufactured a chonometer raised from the wreck of the White Star Line's *Arabic* sunk during the First World War.

Sextant

A sextant is a hand-held navigating instrument for measuring, by reflection and through by a single observation, the angle subtended at the eye by two distant objects. It was the most convenient and accurate instrument devised for use where the observer had a very unstable support, as on board ship, and was in common use by navigators and surveyors. At sea, it was used to determine the altitude above the horizon of celestial bodies. Inshore, it was held horizontally to measure the angles between known landmarks. In conjunction with an instrument called a station pointer, this gave a position without the need for compass bearings. By measuring the angular altitude of a landmark whose height was known, the sextant determined the ship's distance from it. *Titanic*'s Captain and Senior Officers utulized sextants to verify the ship's position and daily run. Fourth Officer Boxhall gave a good description of the use of a sextant aboard *Titanic* in his testimony on the *Titanic* sinking for the United States Senate hearing :

> *When you take stars you always endeavor, as they did that night, to take a set of stars. One position checks another. You take two stars for latitude, and two for longitude, one star north and one star south, one star east and one star west. If you find a big difference between eastern and western stars, you know there is a mistake somewhere. If there is a difference between these two latitude stars you know there is a mistake somewhere. But, as it happened, I think I worked out three stars for latitude and I think I worked out three stars for longitude.*

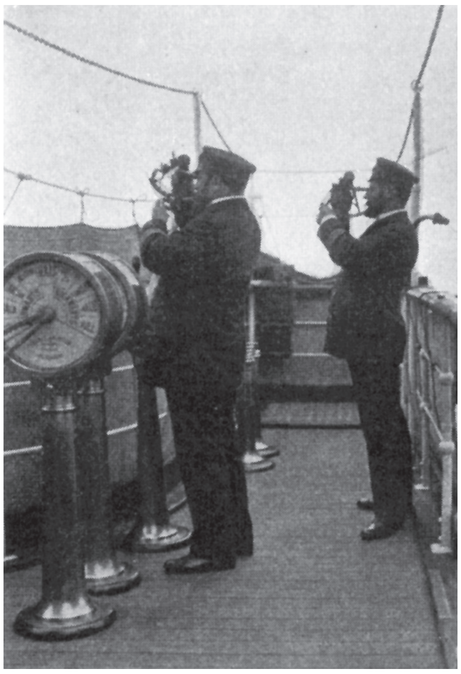
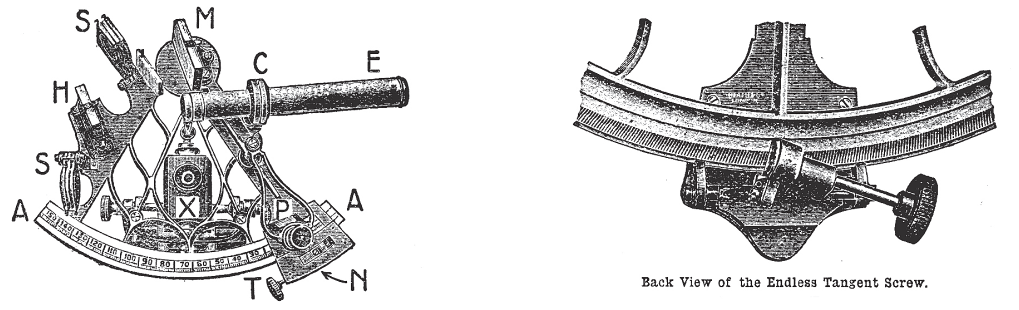


Fig. 22-19 **Sextant in Use** – Officers 'shooting the sun' on an ocean liner, *c.*1912. *(J. Kent Layton collection)*

On large, fast liners, the speed of the ship was a never-failing source of conversation every morning, and most passengers took a share in the many guessing competitions that were arranged, prizes being given to those who most nearly guessed the number of miles covered each day. Some passengers made friends with the engineering officers and tried to learn whether there had been any variations in speed, but that was not considered fair. On *Titanic*, the day's run was generally posted up at the head of the First



Back View of the Endless Tangent Screw.

A A′ is the arc (or limb) graduated from right to left, from 0 to 120° or 150°—subdivided by 10′, 15′ or 20′, according to the size and perfection of the instrument. The best instrument reads to 10″. To the right of 0 is a small space of graduation called the arc of excess.

M N is the radius or index bar, movable along the arc and having a dividing scale *N*, called the vernier.

M is the index glass, a reflector or mirror, which moves with the index bar, and is fixed on it in such a manner that its plane is always over the centre of motion of the index, and perpendicular to the plane of the instrument.

H is the horizon glass, one-half of which is a reflector or mirror, and the other half plain glass, to admit of objects being seen through it; it is fixed perpendicularly to the plane of the instrument, and parallel with the index glass when 0 on the vernier stands at 0 on the arc.

P is the microscope, movable, for reading accurately the divisions of the arc and vernier.

T is a tangent screw for giving a small motion to the index after it has been partially fixed with a clamping screw, which is at the back of the lower end of the index bar and under the vernier.

X—The handle of the sextant, by which it can be held in any position between the vertical and horizontal, is partly shown beneath the index bar.

S are the index shades of coloured glass, to be turned down between the index glass and the object glass, as the eyesight requires, in order to moderate the brightness of an object—as the sun or moon.

S′ are the horizon shades of coloured glass to be turned up, as required, beyond the transparent part of the horizon glass.

E is the telescope to be screwed into the collar *C*, which is a double ring; when the telescope is absent, the collar is the place of the sight vane.

Fig. 22-20 **Sextant** – A typical sextant of the era.

Class Grand Staircase, in main companionways, or in some other conspicuous place. On *Olympic*'s second westbound crossing, the daily runs posted for the passengers over a five-day period read as follows:

Aug 11	50.56	21.32	516	Light S.W. winds, slight sea, fine weather
Aug 12	47.03	34.26	543	Mod. wly. to S.E. winds & fine weather
Aug 13	42.39	45.27	536	Mod. S.E. & S. winds to fresh W. wind. Mod. sea & squally weather
Aug 14	41.22	57.18	544	Fresh & mod. winds, squally, slight sea
Aug 15	40.36	69.30	553	Mod. N.W. winds, slight sea & fine weather, 190 to go.

The location in Third Class for posting the day's run was near the Dining Saloon entrance. The Senior Officers gathered on the bridge at 11.45 a.m. each day in preparation for taking the noon position for determining the day's run. The day's run was calculated by the longitude and engine revolutions compared to the day before. The revolutions were required to be reported to the Bridge at intervals of every four hours. The final figure was then arrived at by the Captain who would post the figures to the passengers as soon as they were computed.

The Lord Kelvin's Patent Motorized Sounding Machines

A 'sounding' is the depth of water alongside a ship. Traditionally, and originating in the days of sail, soundings were taken by casting a weighted line into the water at the bow of the ship and determining how far the line ran out before the weight hit bottom. Sounding machines were designed to take soundings more rapidly and efficiently than could be done by hand. The design of the motorized sounding machines on *Titanic* had been around since 1907; however, on *Titanic* they were fitted with lighted

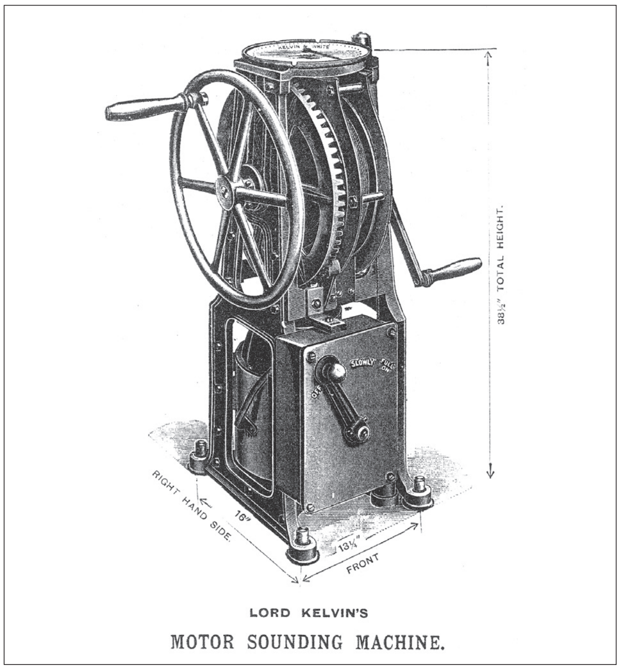

KELVIN & WHITE
SLOWLY
FULL ON
OFF
38½" TOTAL HEIGHT.
RIGHT HAND SIDE.
16"
13¼"
FRONT
LORD KELVIN'S
MOTOR SOUNDING MACHINE.

Fig. 22-21 **Kelvin Sounding Machine** – The motorized Lord Kelvin's Sounding Machine as it appeared in a catalog *c.* 1907. This sounding machine is what would have been found on *Titanic.* The light for the dial can be seen over the edge of the dial on the right side.

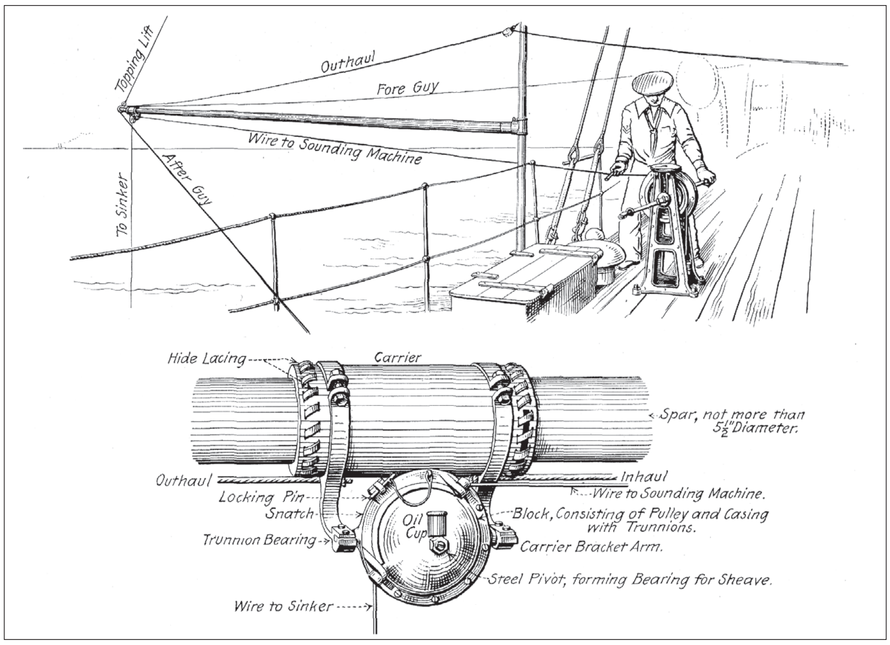

Topping Lift
Outhaul
Fore Guy
Wire to Sounding Machine
After Guy
To Sinker
Hide Lacing
Carrier
Spar, not more than 5½" Diameter.
Outhaul
Inhaul
Wire to Sounding Machine.
Locking Pin
Snatch
Block, Consisting of Pulley and Casing with Trunnions.
Oil Cup
Trunnion Bearing
Carrier Bracket Arm.
Steel Pivot, forming Bearing for Sheave.
Wire to Sinker

Fig. 22-22 **Sounding Machine Illustration** – This was a very common illustration of the period and was widely distributed to maritime publications. It shows the operation of a hand-operated Kelvin sounding machine. Though *Titanic*'s were motorized, these manual models were not outdated by 1912; in fact they would be used for many years to come. The spar and the carrier assembly seen in this illustration are nearly the same as those used on *Titanic.*

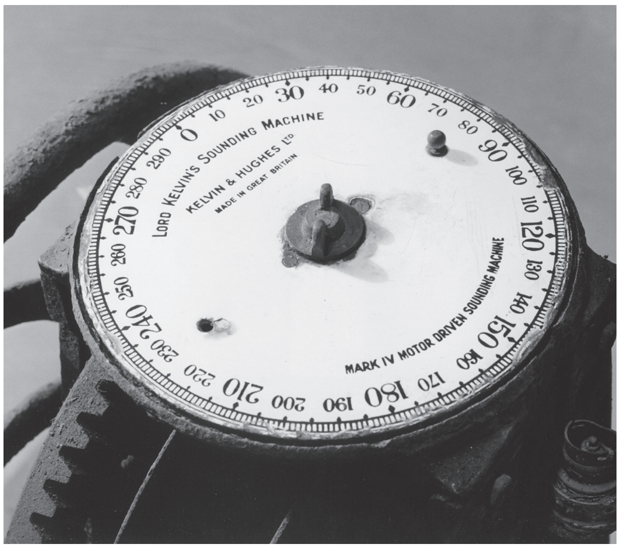
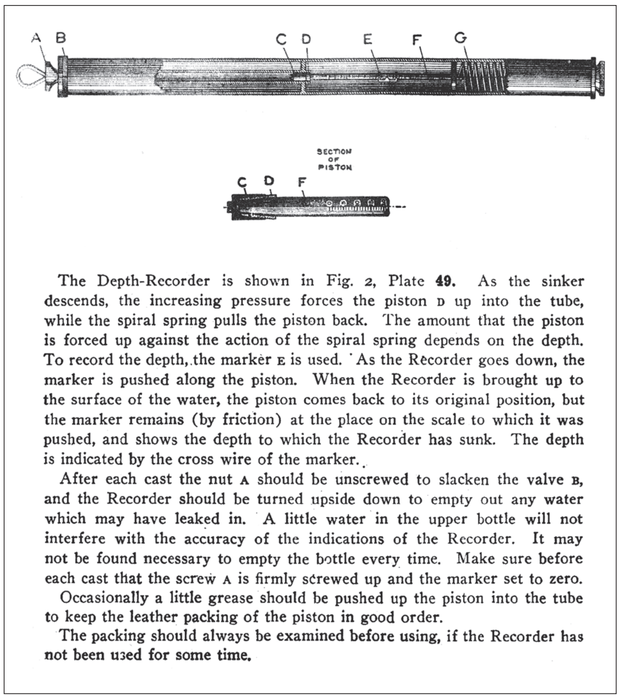

LORD KELVIN'S SOUNDING MACHINE
KELVIN & HUGHES LTD
MADE IN GREAT BRITAIN
MARK IV MOTOR DRIVEN SOUNDING MACHINE

Fig. 22-23 **Sounding Machine Dial** – The dial of a Kelvin & Hughes Ltd motorized sounding machine. These devices apparently worked so well that this example from the late 1940s has only minimal differences from its 1907 counterpart. The socket for the light bulb can be seen at the lower right of the image. This is a prime example of the dictum 'if it's not broken, don't fix it' that is so prevalent in the maritime trades. *(Southampton City Archives/Authors' collection)*


A
B
C
D
E
F
G
SECTION OF PISTON
C
D
F

The Depth-Recorder is shown in Fig. 2, Plate **49.** As the sinker descends, the increasing pressure forces the piston D up into the tube, while the spiral spring pulls the piston back. The amount that the piston is forced up against the action of the spiral spring depends on the depth. To record the depth, the marker E is used. As the Recorder goes down, the marker is pushed along the piston. When the Recorder is brought up to the surface of the water, the piston comes back to its original position, but the marker remains (by friction) at the place on the scale to which it was pushed, and shows the depth to which the Recorder has sunk. The depth is indicated by the cross wire of the marker.

After each cast the nut A should be unscrewed to slacken the valve B, and the Recorder should be turned upside down to empty out any water which may have leaked in. A little water in the upper bottle will not interfere with the accuracy of the indications of the Recorder. It may not be found necessary to empty the bottle every time. Make sure before each cast that the screw A is firmly screwed up and the marker set to zero.

Occasionally a little grease should be pushed up the piston into the tube to keep the leather packing of the piston in good order.

The packing should always be examined before using, if the Recorder has not been used for some time.

Fig. 22-24 **Depth Recorder** – General instructions for use of the depth recorder, from the operations manual of a Kelvin sounding machine.

dials. The sounding machines were mounted on the Boat Deck on both sides of the Officers' Quarters deckhouse forward. They were located just inboard of the collapsible lifeboats mounted on the deck and were covered with wooden cabinets when not in use to protect them from damage. Wooden spars were mounted on pivots attached to the outboard bulwarks port and starboard just aft of the emergency cutters; these spars held the lines from the sounding machines well clear of the side of the ship when soundings were being taken.

The Kelvin Sounding Machine consisted of a steel frame bolted to the deck, with a drum wound with 100 fathoms (600ft) of seven-strand, galvanized flexible steel wire rope. *Titanic* carried one extra wire-wheel drum for the sounding machines as a back up. The motor was in a metal case fixed to the base of the machine. It was designed for a power supply of 100 volts but would work efficiently with as little as 80 volts. The motor shaft passed vertically through the top of the case, and a small bevel wheel was keyed to it. A watertight box was fastened low on the front of the machine, which contained the speed controller and the motor switch. The handle of the switch was fitted with a spring that was extended when the switch was moved to the 'ON' position. If the handle was released, it returned to the 'OFF' position and the motor stopped.

Two men, referred to as a brakesman and a leadsman, did the work of taking a sounding under the supervision

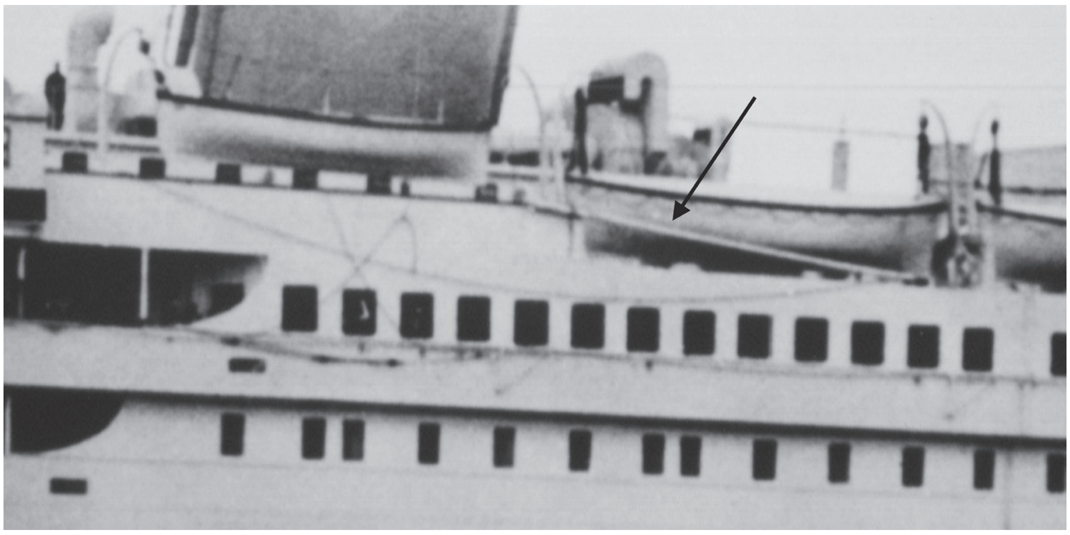


Fig. 22-25 **Spar Secured for Sea** – In this photograph of *Titanic*'s port side, taken as she departed Southampton, the sounding spar (indicated with an arrow) is seen in the stowed position. It appears that the spar is rigged for ready use here, however, as the lines are fitted and hanging loose.

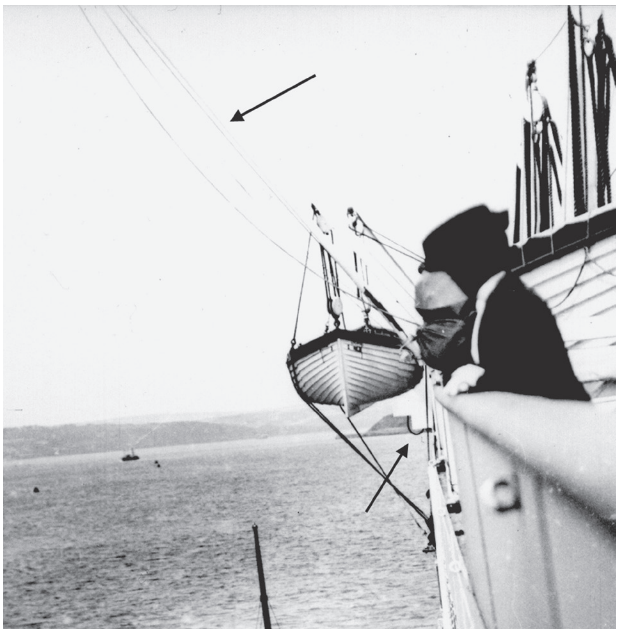


Fig. 22-26 **Sounding Spar** – In this image taken at Queenstown, the port-side sounding spar (indicated with an arrow at top) is seen extended outward. The bracket for securing the spar is also indicated with an arrow (seen below the emergency cutter). Also notice the dark patch on the spar where the painter missed with white paint. *(Cork Examiner photograph/ Campbell McCutcheon Collection)*

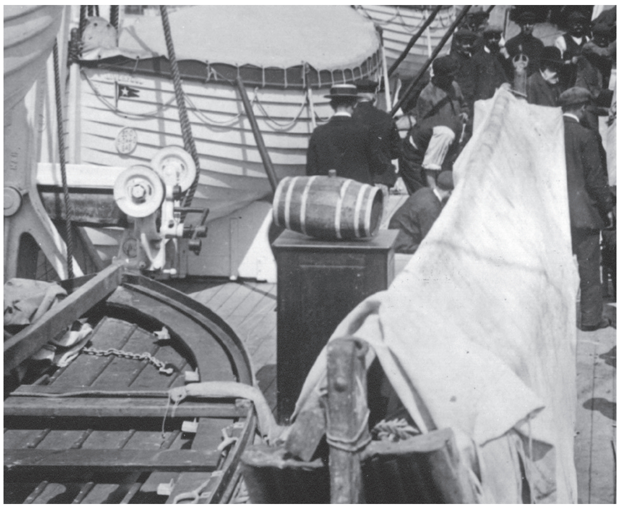


Fig. 22-27 **Wooden Cover Over Sounding Machine** – In this image taken on *Olympic* shortly after *Titanic*'s sinking, a lifeboat water breaker is resting on top of the wooden box covering one of the sounding machines.

of an officer who noted the reading of the dial and referred to the Speed and Depth Table to ascertain the depth. To take soundings, the spar was put into position, the wire was snatched in the block of the carrier, and the sinker was lowered over the side. The wire was eased or checked by turning the skeleton wheel in the direction of heaving-in to brake, or in the opposite direction to ease the wire. With the sinker at the surface of the water, the pointer was set to zero and the operator placed the loop of the feeler pin over his right wrist.

To 'let go', he held the skeleton wheel with both hands and gave it one turn in the direction opposite to that of heaving. As the wire ran out he released the wheel and put the feeler pin on the wire, pressing gently, catching the handle of the switch on the left hand. As soon as the wire slacked, the motor switch was pushed all the way over to heave in the line at full speed. The wire was guided on the drum evenly by a man holding it with a pad of oiled canvas. When the pointer showed 10 fathoms (60ft), the motor switch was eased back gradually and then stopped before the swivel reached the carrier block.

Attached to the end of the wire was a metal cylinder; beyond that was a heavy sinker connected to it by a short length of plaited rope. The rope that carried the sinker was connected to a link that was permanently attached to the end of the wire. The metal cylinder carried a slender tube of glass, closed at one end and coated on the inside with chloride of silver, which changed color upon actual contact with sea water. This tube was placed in the metal cylinder with its open end down. As it sank, the water rose in the tube and the air with which the tube was originally filled was compressed with a force relative to the head of the water acting upon it. As this head depended upon the depth, it followed that the compression of the air – and hence the height to which the water rose in the tube – became a measure of depth.

With properly coated tubes, carefully used, the limit of discoloration was marked by a sharply defined line, and the depth corresponding to this line was read off by a scale marked in fathoms. The tube readings were a bit antiquated by 1912, as the dial located at the top of the machine was found to be reliable within acceptable limits.

The sounding spar was approximately 30ft long and was no more than 5½in in diameter, tapering slightly at both ends. The use of spars made it possible to mount the machines at any point along the beam. The heel of the spar was fitted to the bulwark with a swivel bolt. For convenience in shipping and unshipping, the heel permitted the spar to be guyed forward or aft as well as being topped up or lowered down. The other end of the spar was fitted with a band and three lugs. A topping lift, to support the spar in a horizontal position, was secured to the lug at the upper part of the band; guys were secured to the lugs on the forward and after sides of the band. When in use, the spar was held in a horizontal position at right angles to the fore-and-aft line of the ship by the topping lift and guys.

A small sheave was fixed in the mortise at the outer end of the spar just within the band previously mentioned. A line was hove through the sheave hole to serve as an out-haul for hauling the carrier or traveler out on the spar. One end was secured to the brackets of the carrier and the other end was brought inboard to a cleat near the heel of the spar. Sliding in and out on the spar was a cylindrical carrier with a pulley for the wire. The carrier was moved in and out by hauling-lines, the out-haul reeling through a sheave in the end of the spar. The pulley had free play in all directions.

The Hand Lead

The ordinary method of ascertaining the depth of water without the use of a sounding machine was by casting a weighted line into the water near the ship, and noting how far the line ran out once it entered the water. A hand-lead, used for moderate depths, weighed anywhere from 7 to 14lb. A well-practiced leadsman could get soundings in depths up to 5 fathoms with the ship going 8 knots, although soundings by hand were rarely taken when the ship had any significant way on. If reliable soundings were required in depths greater than this, the speed of the ship was reduced or the motorized sounding machine used.

A lead line had a mark for every fathom and half-fathom up to 10 fathoms; for part of the range (covering the depths that were critical for the ship using it) it was marked in feet. Thus, if the ship drew 20ft of water, there would be a mark at every foot between 20 and 30. The soundings were reported by the leadsman in fathoms and fractions for depths generally greater than 6 fathoms, and in feet for depths below this. The lead line was of a material that would not shrink or stretch excessively after being wet and then dried.

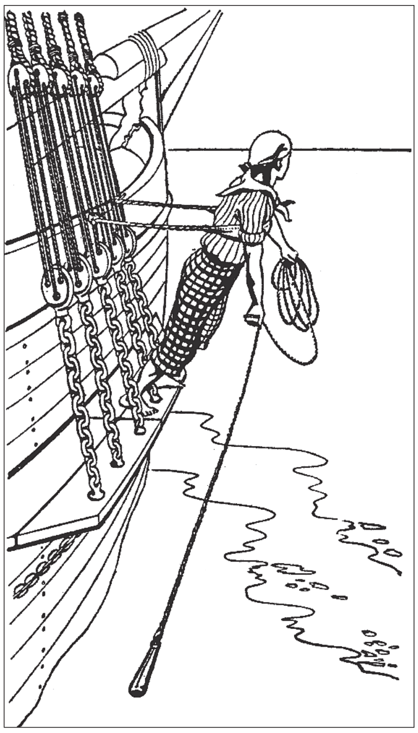


Fig. 22-29 **Leadsman in the Chains** – A leadsman in 'the chains' in the days of the sailing ships.

The lead lines were checked by the Board of Trade Surveyor who looked for the proper markings, being:

At 2 fathoms a piece of leather split in two strips.
At 3 fathoms a piece of leather split in three strips
At 5 fathoms a piece of white bunting.
At 7 fathoms a piece of red bunting.
At 10 fathoms a piece of leather with a hole.
At 15 fathoms a piece of blue bunting.
At 17 fathoms a piece of red bunting.
At 20 fathoms a strand with two knots tied in it.

It was commonplace to have the lines fitted with calico for white marks, bunting for red marks, and serge for blue marks, because it was possible to distinguish these by feel in the dark.

Among *Titanic*'s hand-lead equipment were also two-hand held sounding rods. These were for portable use, and in photographs of *Titanic* can be seen leaning against the bulwarks of A Deck, port and starboard, in the area of the after cargo cranes.

General specifications of lead equipment carried on *Titanic* were as follows:

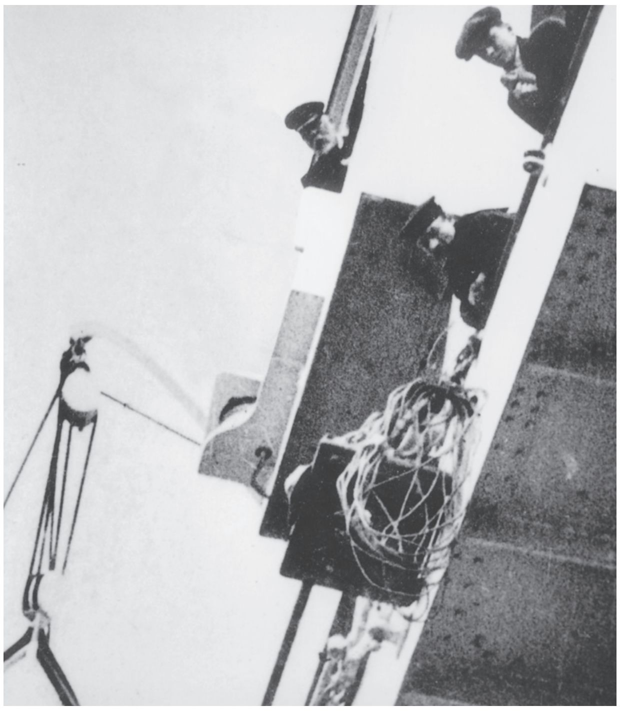


Fig. 22-28 **Leadsman's Platform on *Titanic*** – In this well-known Father Browne image taken from the tender at Queenstown, the leadsman's platform is clearly visible here in its folded-down position, with the lead line coiled on top of it. This image is commonly misrepresented as Captain Smith looking down into the emergency cutter, but this is an illusion based on the angle of the photograph, as the cutter was located well aft of the Bridge wing. Smith is, instead, looking down at the tender. *(Father Browne photograph/Authors' collection)*

2 deep-sea leads – one at 8lb and one at 56lb.
2 deep-sea lead lines – each 120 fathoms of 1½in line, one marked
2 deep-sea lead line reels
4 hand leads – two at 7lb and two at 10lb
4 hand lines, each 30 fathoms of 1in line, two marked
2 sounding rods and lines, each 12 fathoms

Leadsman's platforms

Motorized sounding machines were coming more into use by 1912, but when the ship was plying shallow waters soundings had to be taken more frequently and the lead was cast by hand. Platforms for the leadsmen were hinged to the outsides of the A Deck bulwarks near their forward ends, on both port and starboard sides. These platforms placed the leadsman over the water and gave a firm footing, although for safety an apron and wide canvas belt helped support the leadsman and prevented him from falling. The platforms were placed just below and forward of the Bridge Wings, so that the navigating officer could hear the various soundings called out by the leadsman.

It should be evident that these platforms were to be secure and well-constructed. The leadsman's platforms were framed up with two stiles and two rails; the stiles were placed athwartship and the rails fore-and-aft. The stiles and rails were made of teak and were 3¾in x 2in, and mortised-and-tenoned together. The space between was filled in with grating. The grating was made up of 2in x 1½in rectangular teak bars mortised to the rails. The whole of this framework was jointed and all the joints well-painted before they were put together. The grating was nailed together by headless nails of galvanized iron. The fittings, which were all of galvanized iron, formed an important feature of the construction. Everything was arranged so that each platform could be lifted up against the bulwark when not in use. Each platform was hinged to the ship's side by means of a pair of hinges working on a bar. The hinges were carried right across the platform, and the eye bolt to which the supporting chain was attached went through the hinge. The hinge bar was supported by lugs that were riveted to the ship's side. The outer edges of the platform were supported by chains with an eye through the platform and an eyebolt riveted through the bulwark.

On *Titanic*, platforms for the leadsmen were also located at the after end of the ship, the overhanging ends of the Docking Bridge serving this purpose. Unlike *Olympic* with her retractable platforms, *Titanic*'s Docking Bridge was built with its structure permanently extending about 2ft over the sides of the hull, thereby eliminating the need for retractable structures.

The Patent Log

The log was a device for measuring a ship's speed, the name being derived from the original device which was a simple piece of wood – the 'chip log', tied to a line and thrown into the water. The speed of the ship could be calculated based on the time the log took to pass from stem to stern, and was measured in terms of the knots on the log line. Using a 'Gunter's Scale', a seaman could translate fathoms or feet per minute or half-minute into miles per hour. The actual knotting of the log line was in intervals thought originally to be proportionate to fractions of miles, but the 'knot' was 6,080ft against 5,280ft for the land mile. One man or boy stood with the drum or reel for the line held over his head by the handles, while another reeled off several fathoms of the line and then heaved the attached log overboard on the lee side. As the ship sailed forward the log stayed at a constant position in the water while the line continued to be paid out. The seaman with the reel or drum watched the line, and the other operator watched a sand glass. When a piece of white bunting on the log line reached the rail, the seaman with the drum shouted 'turn', and his companion turned over the sand glass. At the end of the operation, at the final running-out of the sand, the man with the drum shouted 'stop'. The line was seized and prevented from paying out further, so that the ship began to tow the log, from which a wooden plug was pulled out by the sudden strain to absorb the shock. The log was then hauled aboard. The speed of the ship was calculated from the time it took for the sand glass to run out, in terms of the knots spaced at regular intervals along the line and the 'line length' from the position of the white bunting.

Various ideas for mechanical logs were advanced in the eighteenth and nineteenth centuries, but many of these came to naught. One of the first reasonably successful inventions was the hydrometer, or 'English log', as developed by Foxon of Deptford. Fixed to the taffrail, it recorded the rotations of a helix towed astern of the ship, three dials indicating tens of miles, miles, and tenths of miles. But the helix, which was designed to rotate like a screw, was not always accurate and so eventually the hydrometer was abandoned. About 1800, Gould, in the United States, developed his 'milometer' that was towed astern with a submerged counter worked by a variable-pitch propeller. This could be adjusted to the average speed of the ship if known. Massey's mechanical log of 1802 swiftly superseded Gould's invention, although it was designed along very similar lines. In 1851 Thomas Walker, who started by manufacturing the Massey's log under license, introduced his own 'harpoon' log which saw widespread use. In 1879, the Walker Company patented its 'Cherub' log, which had a counter mounted on the rail, a torque-free line, a flywheel, and a propeller.[11] With the success of Walker's logs came more powerful models: the 'Neptune' in 1899 and the 'Trident' in 1905. The Walker Company developed its electric log in 1902, but it was not used much commercially until 1924.

Titanic was provided with a Walker's Patent Neptune Taffrail Log, which was some 9in in length with a 5in dial. This device consisted of a rotator, in principle like the propeller of a ship, which was towed through the water and thus made to rotate with a velocity varying directly with the speed of the ship. The motion of the rotator was transmitted by a cord to a series of gears and dials, the dials registering the distance corresponding to the revolutions of the rotator. The main dial was marked around its edges from 0 to 100, these figures representing miles. A brass hand pointed to the number of miles run. There was also an inset dial with a smaller hand, much like the second hand on a watch, which indicated tenths of a mile. A second inset dial indicated the passing of every 100 miles up to 500. The registration mechanism was mounted on the Docking Bridge at the after end of the ship and a long line was used between it and the rotator. The record of a patent log was one of distance and not of speed. To find the speed, a note was made of the run compared to a given length of time.

Patent logs generally registered much truer in slow vessels than in very swift vessels, but no log in a heavy head sea was to be trusted; they could act as a rough guide but that was all.

The length of log line used had much to do with the working of the log. The proper length used under ordinary circumstances was about 40 fathoms and was made up of strong hemp specially made into sennit line. However, it was found that a greater length of line was needed for higher speeds and for ships that rode higher in the water.

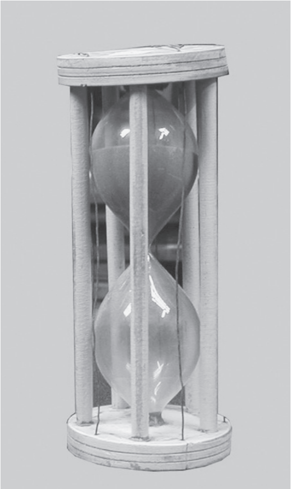


Fig. 22-30 **Log Glass**.

Logs were commonly accompanied by instruments for changing the pitch of the rotator blades to correct an error in running. But unless the error was very great, it was considered preferable to leave it and apply the error found from observation.

The revolution of the screws of the ship afforded a valuable check upon the log and means of replacing it if necessary, provided the record of revolution was kept in connection with the record of the log, and provided also that this same record gave the draft of the ship and the condition of the bottom. The fact that vessels like *Titanic* made trip after trip at almost unvarying speed enabled speed calculations with great accuracy by revolution alone (however a 'propeller slip table' was usually devised first, something *Titanic*'s officers were never able to complete).

Titanic's log[12] was deployed continuously while at sea and checked every two hours by the Quartermaster stationed on the Poop Deck. The log was reset at noon every day when the solar observations were made for the ship's position.

A common problem with these instruments was that they caught a lot of grit from the smoke of the funnels blowing aft, causing them to require regular cleaning and oiling. At the end of a long passage, the log was taken in and disassembled for cleaning by a competent person. At least once a year the log was shipped to the manufacturer for overhauling, and it was important that the instrument went to the maker and not the ship-chandler, because the maker knew the intricacies of the device better than anyone else. Taffrail logs could get good results as long as they were well cared for. They were also to be towed on the weather side of the ship – if towed on the lee side, the rotator could be fouled by rubbish or ashes discharged overboard.

Titanic was supplied with 14-second log glasses, which were like the well-known hourglass filled with sand. As mentioned above, this was the only way to measure distance at one time, and ships would either use 28- or 14-second glasses. The glasses supplied to *Titanic* were used to approximate speed based on the distance recorded on the dials of the patent log. A watch with a second hand could also be used if available.

General specifications for log equipment supplied to *Titanic* were as follows:

Two Walker's Patent 'Neptune' logs complete with lines and governors.

Two logbooks and diaries
Three log lines, each 40 fathoms of best hemp.
Two log slates
Two 14-second log glasses

Submarine Signaling

Titanic was fitted with the Submarine Signal Company's apparatus for receiving submarine bell signals. With this system the sound of submarine bells was received through the hull of the vessel. Submarine bells, used as fog signals, were located on lightships, at lighthouses and even a limited number of specially equipped buoys. The bells were established by Trinity House in Great Britain and the Lighthouse Service in the United States. The system was a great improvement upon that of fog signals sounded through the air, as the direction and distance of an audible foghorn often could not be reliably ascertained in the very conditions in which it was depended upon. Sound travels underwater at a speed 3¼ times greater than through air, and without regard to weather conditions. Typically a submarine bell could be heard from a distance of twelve to fifteen miles or more. By locating the direction of the sounds, the position of the vessel, when in the vicinity of the coast, could be accurately ascertained.

By 1912, submarine bells were located throughout the British Isles and, to a lesser extent, off other countries near harbor entrances, headlands, and other key locations. The bells were attached to fixed buoys or lightships about 30ft below water, or secured to the seafloor offshore from a lighthouse. Bells at lighthouses were sounded by electric current; bells at lightships, by compressed air or other mechanical means; and at buoys, by wave motion. The signals were received aboard ship by small tanks containing microphones, placed on the inside of the hull of the vessel on the port and starboard sides of the forward hold below the water level. These microphones, which could be termed the 'ears' of the ship, were connected to a direction indicator on the bridge by ordinary telephone cable. By moving the switch on the indicator box to port, only the port 'ear' was in operation. By changing the switch to starboard, the operator switched over to the starboard 'ear'. If the bell was heard only through the port microphone, it could safely be assumed that the bell was located somewhere to port. Should, however, the bell be dead ahead, the sound would be heard equally by both 'ears'. If desired, by gradually altering the ship's heading until the sound was heard equally, the bearing to the bell's location could be reliably ascertained. The signals, therefore, not only gave warning of the ship's proximity to a point of danger, but also assisted her progress in a fog: the navigating officer could make use of them to tell with more certainty where the ship was located, as every submarine bell could be identified by its unique number of strokes.

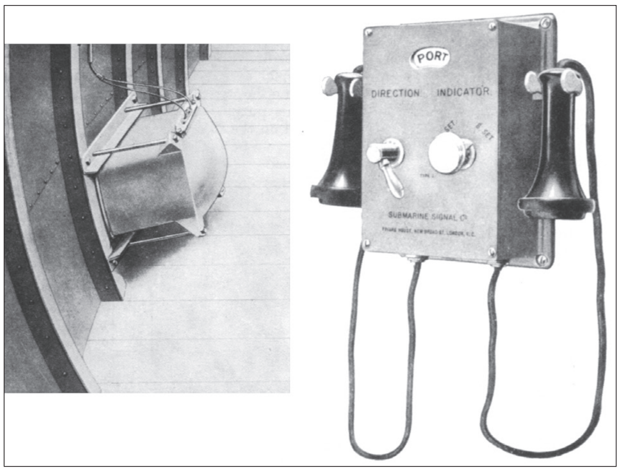


Fig. 22-31 **Submarine Signalling Equipment**. – These images show examples of the typical submarine signalling equipment aboard ships of *Titanic*'s era. At left, the housing for one of the two microphones fitted against the shell plating beneath the waterline at the bows; at right, the receiving equipment.

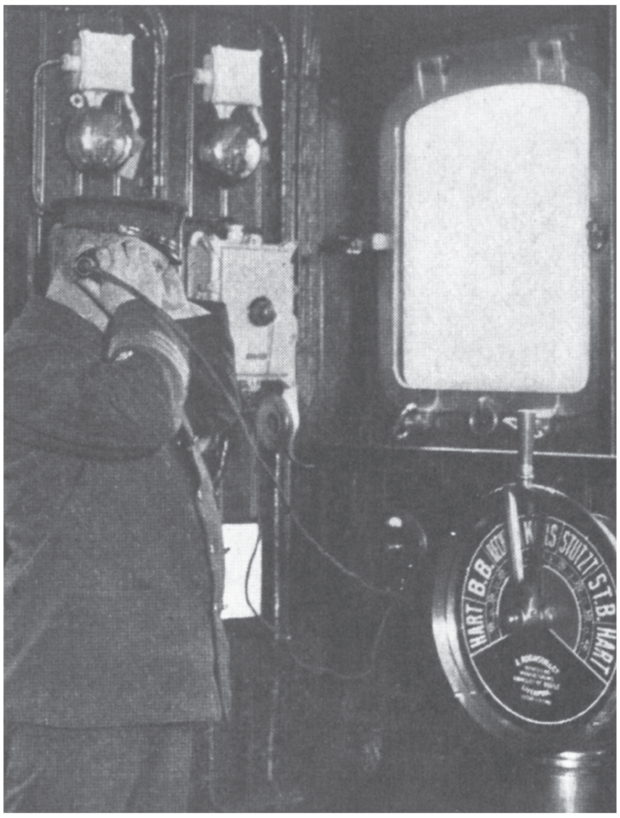


Fig. 22-32 **Submarine Signaling Equipment in Use** – In this image, an officer of a German vessel listens to the submarine bell of a lightship. *(J. Kent Layton collection)*

Electric Clocks

Though not technically part of *Titanic*'s navigational equipment, log entries and watch-keeping did require a time reference, and of course the time of day needed to be provided throughout the ship for passenger convenience. There were forty-eight clocks installed throughout the ship, which were slaved to a pair of master clocks secured within watertight cases in the Chart Room.

The two master clocks worked in unison with each other, registering the exact same time. The ship gained from thirty-five to forty-five minutes each day when going westward and lost a corresponding amount of time when returning to Europe. To allow for this difference in time, the time on the master clocks was adjusted each day at midnight by the officer in charge, who put them backwards or forwards according to the longitude. The midnight hour was used for changing the clocks because of the noise they would make from jumping over so many minutes. The usual time at sea for this practice was noon, but the noise generated by *Titanic*'s electric clocks moving forward or backward could be disturbing during the waking hours, and hence it was done at midnight. Notices indicating time changes were put up in the main passenger companionways.

The clocks slaved to the master clocks did not record seconds, but jumped every minute. The only second hands present were on the master clocks. When the minute hand on the master clock moved past the line of the minute, a switch released a contact, and the rest of the clocks throughout the ship responded by jumping ahead one full minute. Besides being fitted in *Titanic*'s public spaces, these clocks were utilized in the Wheelhouse, Marconi Operating Room, Reciprocating Engine Room, and wherever time recordings were necessary.

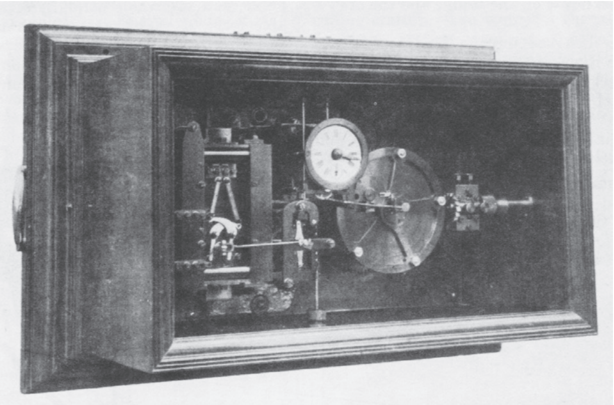


Fig. 22-33 **Master Clock** – One of the Magneta master clocks fitted to *Olympic* and *Titanic*. The ship's time was adjusted every night at midnight. (The Shipbuilder/*Authors' collection)*

The electric clocks were supplied by the Magneta Time Co. Ltd, and all were actuated on the Magneta system, which obviated the use of galvanic batteries and contact points. Specially designed junction boxes were fixed throughout the vessel, so that additional clocks could be added at any time without disturbing the existing wiring. These clocks contained the necessary modifications for conditions aboard ship, with a balance escapement similar to that used on marine chronometers.

Barometer

Used for predicting weather, the barometer is an instrument with which to measure the variations in the weight or pressure of the atmosphere. When the barometer was 'falling', for example – signifying a drop in pressure – rain or other foul weather could be expected within twenty-four hours. Two kinds of barometers were in use for observations at sea, the mercury and the aneroid type. The mercury barometer consisted of a glass tube closed at one end and filled with pure mercury, all air being carefully excluded. The tube was then inverted and its open end immersed in a small reservoir also containing mercury so as to prevent air entering the tube. The pressure of the atmosphere on the surface of the mercury in the reservoir exerted a downward force that acted against the weight of the mercury in the tube. Decreasing atmospheric pressure reduced downward pressure on the reservoir, allowing the mercury in the column to fall. High pressure had the opposite effect. Barometric pressure was read by reading the height of the column in the tube. British instruments were graduated in inches and decimals of an inch, the average height at sea level being rather less than 30in, though the mercury sometimes rose to nearly 31in and fell below 28in.

The mercury barometer was very delicate and was required to be hung so it could swing freely, maintaining a truly vertical position. It was kept out of the way from damage, and was to be read at a minimum of every four hours – and in doubtful or bad weather more frequently – and the reading entered into the log book.

The aneroid barometer consisted of a thin, corrugated, elastic metal drum partially exhausted of air. Fastened to the inside surface of the drum was a spring which prevented the drum from collapsing from the partial vacuum. Small changes in external air pressure caused the drum to contract, and this contraction acted upon the spring, causing it to compress. This movement, albeit slight, was transmitted by a system of levers to a small fine chain wound round the spindle of the pointer, the

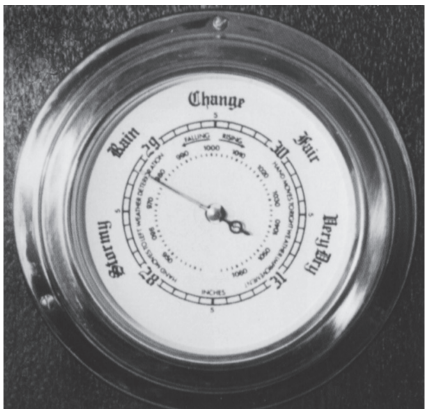


Fig. 22-34
Barometer – An example of a common aneroid barometer for ship use during *Titanic*'s era.

pointer being positioned central to a dial from which the atmospheric pressure could be read. A hairspring attached to the spindle permanently acted against the chain and kept it taut.

The advantage of using an aneroid barometer was that it could be more conveniently placed in a small chart room where it would not be desirable to have a mercury barometer; also it showed a change of atmospheric pressure more rapidly than a mercury barometer. One of *Titanic*'s aneroid barometers was raised from the wreck; it was made by Sharman Neill of Belfast and had a white dial mounted within a brass circular frame.

Thermometer

This instrument showed changes of heat and cold without being affected by air pressure. Aboard ship it was used for measuring both air temperature and water temperature. This was not for mere records' sake; the outside temperature affected the ship's ventilation requirements, and safe navigation, at times, also depended on it – a rapid and abnormal drop in air temperature might indicate the presence of ice in the area, for example. Water temperature was normally taken by lowering a bag on a 20-fathom line over the side of the Boat Deck, scooping the bag full of water, and hoisting it back up. A thermometer would then be submerged in the water contained in the bag indicating the temperature. *Titanic* did not have a canvas bag, as it appears she was not supplied with one at the time of her sailing. Instead, a paint bucket was rigged up with a weight in the bottom to serve the same purpose. The Quartermaster was required to take the air and water temperature of the water every two hours, and report the readings to the Junior Officer of the watch.[13]

Titanic was equipped with two large copper thermometers. Of the various scales in use at the time, the thermometers on *Titanic* were marked in degrees Fahrenheit, which has the freezing point of water at 32° and the boiling point at 212°. This was the same scale in ordinary land use in Great Britain in 1912.

Clinometer

The clinometer was a device that indicated the degree of port and starboard list of the ship. The components were mounted within a round brass watertight enclosure with a glass face, and consisted of a needle indicating degrees on a white card. *Olympic*'s clinometer in 1935 was recorded as being 'a 10in. diameter mercurial wall clinometer made by Sharman Neill, Belfast', and could very well have been the same for *Titanic*. Being an elaborate form of a 'level', it had to be mounted on the centerline of the ship.

Quartermaster Robert Hichens stated in the British Inquiry into the loss of *Titanic* that Captain Smith:

> Came back to the Wheelhouse and looked at the commutator[14] in front of the compass, which is a little instrument like a clock to tell you how the ship is listing. The ship had a list of 5° to the starboard.

Miscellaneous instruments and charts

General specifications of miscellaneous navigation instruments and related equipment on *Titanic* were as follows:

One telescope with ship's name
Two megaphones
One Norwegian foghorn
One gong fog signal
One pair large dividers
One pair 18in 'Fields' parallel rulers

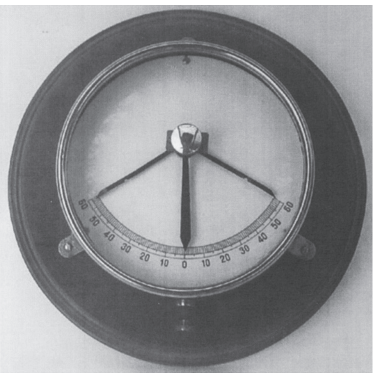


Fig. 22-35
Clinometer – A clinometer or 'inclinometer' as it is sometimes called. The type seen here would have been similar to that fitted on *Titanic*. It should not be confused with the small spirit clinometer mounted to the face of the binnacle. An instrument of this kind was supplied to *Titanic* for mounting within the Wheelhouse, and others may have been mounted in other areas of the ship such as the Chief Engineer's quarters.

Two log books and diaries
Two log slates

General specifications for charts and navigational references on *Titanic* were as follows:

One chart Belfast Lough
One chart Irish Channel, North sheet
One chart Irish Channel, South sheet
One chart English Channel, West sheet – Milford Haven to Plymouth
One chart English Channel, Middle sheet – Portsmouth to Plymouth
One chart Owers to Christ Church, with Spithead and the Isle of Wight
One chart Southampton Water
One chart Great Ormes Head to Liverpool
One volume *Burwood's Azimuth Tables*, 30° to 60° latitude
One copy of *Lights & Fog Signals of the World*
One tide table
One nautical almanac

Navigational charts and sailing directions were supplied by the firm of Philips, Son and Nephew.

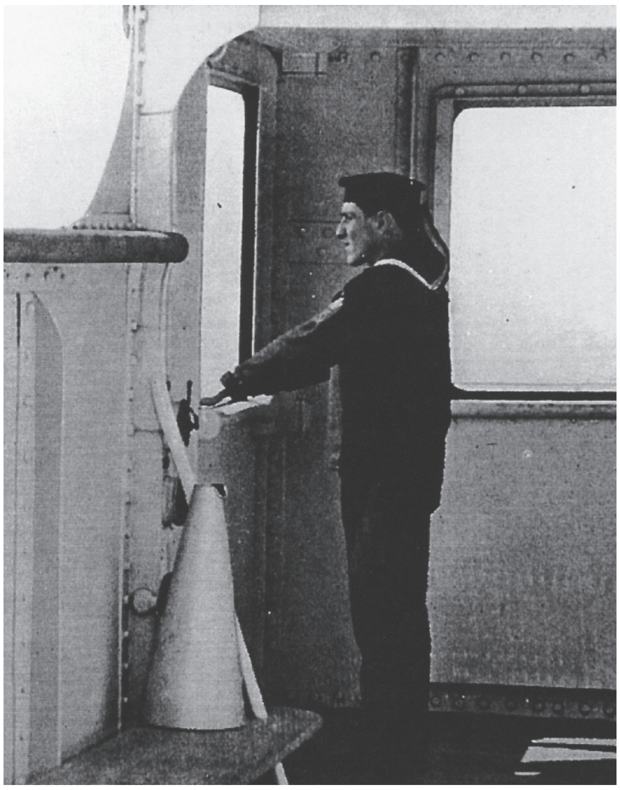
Binoculars

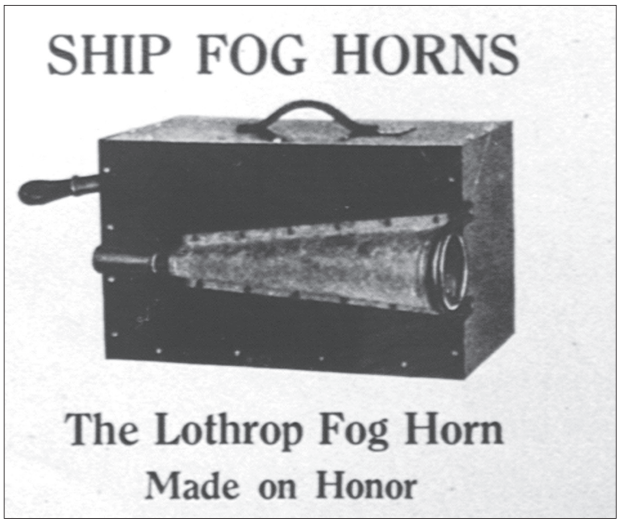
The fact that the lookouts had no binoculars aboard *Titanic* caused her to become the 'poster child' for carelessness in many forums at the time. However, captains of other ships and *Titanic*'s surviving officers all verified that binoculars were not generally used by lookouts. They cited many reasons for this, and were probably quite correct. It is interesting to note that the binoculars owned by *Titanic*'s original 2nd Officer, David Blair, were one of the few instruments known to have *Titanic*'s name engraved on them. Testimony given at the Board of Trade hearings documents Blair's binoculars as being inscribed 'THEATER, MARINE AND FIELD' and 'SECOND OFFICER, S.S. "TITANIC"'. 'Theater, marine and field' indicated a setting on the apparatus to adjust the field of view. A pair of binoculars was issued to each Senior Officer, and when the officer was on duty could be stowed in a teak box located on the bulwark of either Bridge wing. An additional pair of binoculars was provided to the Bridge; these were commonly referred to as 'Pilot Glasses'.

STEERING

Steering commands

The helm was not originally considered the ship's steering wheel nor was it the ship's rudder. It more closely referred to the 'tiller', which was the method of steering early sailing vessels. The tiller consisted of a long wooden arm





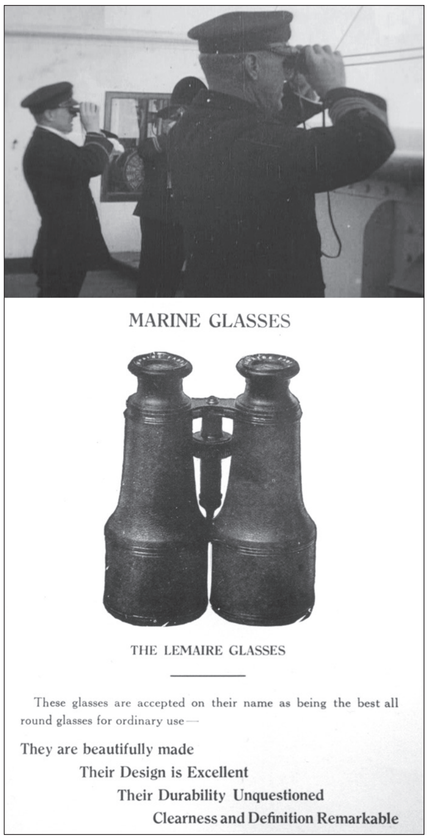
Above Fig. 22-37 **Fog Horn** – This image from a Kelvin catalog shows a typical non-powered foghorn of the era. These devices were manually operated.

Left Fig. 22-36 **Megaphone** – In this posed photograph, a crewman stands inside *Olympic*'s starboard Bridge wing cab. Resting on the step is one of the ship's megaphones.

connected to and extending forward of the ship's rudder post. In order to turn the ship to port, the rudder must be made to move toward that side so that it can act against the flow of water along the hull on that side, thereby effecting a sideways movement. To turn the ship, the tiller was put over to one side or the other, and as the tiller arm extended forward of the rudder post, moving the rudder to one side required the helmsman to push the tiller in the opposite direction. Thus, when the tiller was moved to port the ship's bow swung to starboard and when the tiller was put over to starboard the ship's bow went to port. As ships grew larger, the size of the rudder exceeded the ability of a man to handle a tiller by manpower alone. The tiller post was then shifted to the shelter deck below, and a system of pulleys with ropes or chains was linked to a wheel above. Central to the wheel was a drum around which the line took a number of turns; turning the wheel thereby moved the tiller to one side or the other. But although the wheel took over for the tiller as a means of steering the ship, the definition of 'helm' remained in association with the latter.

Titanic had three wheels. The main steering wheel was located in the Wheelhouse, and this is where the ship was normally steered from at sea. A secondary wheel was located in the Navigating Bridge just forward of the Wheelhouse, and a third wheel was located on the Docking Bridge on the Poop Deck aft.

Titanic's main steering wheel acted the same as did the wheel on all British vessels of the era in that it was turned in the opposite direction to the helm command. To 'starboard the helm', the top of the wheel was turned to port and the ship's head went to port. To 'port the helm', the top of the wheel was turned to starboard. Relative to the sequence of events on the night of *Titanic*'s sinking, this had, and even still has, caused endless confusion to modern mariners and historians alike. When Quartermaster Hichens received the order 'hard a-starboard', he was being given a command to turn the wheel counter-clockwise, thus turning the bow to port. As previously noted, when *Titanic*'s wheel was put 'hard over', the rudder was able to turn a maximum of 40°.



MARINE GLASSES

THE LEMAIRE GLASSES

These glasses are accepted on their name as being the best all round glasses for ordinary use—

They are beautifully made
Their Design is Excellent
Their Durability Unquestioned
Clearness and Definition Remarkable

Fig. 22-38 **Marine Binoculars** – At bottom, a page from a Kelvin & James White Ltd catalog advertising marine binoculars. At top, Captain Hayes and his officers look over the forward bulwark of *Olympic*'s Bridge wing in the early 1920s.

Wheel pedestals and wheels

The ship's wheels on the Navigating Bridge and the Docking Bridge were mounted on a horizontal shaft extending out from a vertical brass pedestal. The Navigating Bridge pedestal was different from its Docking Bridge counterpart in that its shafting connected to the telemotor in the Wheelhouse just aft of it, whereas the shafting of the Docking Bridge wheel linked directly to the control rods of the steering engines. The number of turns of each wheel was generally limited to four between amidships and 'full helm' ('hard over') in either direction – or, in other words, eight turns lock-to-lock. An indicator on top showed the amount of helm in both turns of the wheel and in degrees.

The wheel pedestal on *Titanic*'s Navigating Bridge was 34in tall, with a teak steering wheel 3ft 9in in diameter. It was brass lined, with a center hub of about 6in in diameter. The wheel in the Wheelhouse was 3ft 6in in diameter, mounted 32in from the deck level. The wheel shaft passed through the steering binnacle via a brass shaft, and attached to the Brown's Patent Telemotor immediately ahead.

The Brown Telemotor

For her main steering wheel, *Titanic* was fitted with the well-known telemotor gear of Brown Brothers & Co. Ltd of Edinburgh. Unlike wheels that worked by direct mechanical linkage, the telemotor was a hydraulic steering mechanism. It employed a single cylinder forward and a corresponding cylinder at the steering engine. There was a duplicate cylinder in the steering engine compartment that could be engaged in an emergency. The after cylinder was fitted with centralizing springs that served to return the rudder automatically to midship position when hydraulic pressure was removed.

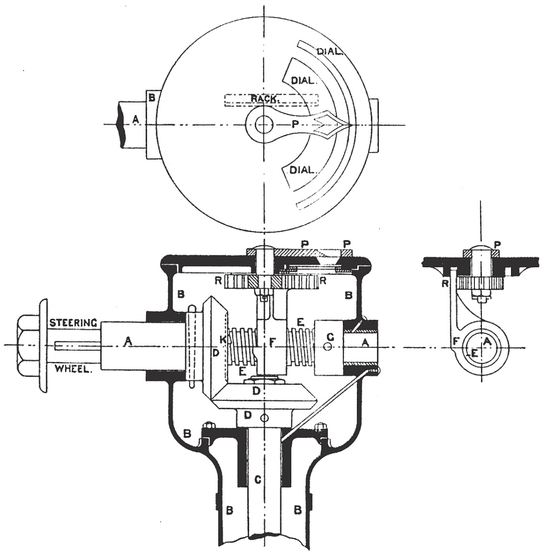
If the wheel was released, the spring compression of the receiver cylinder forced the fluid through the pipes until the center or by-pass annular space was reached by the transmitter piston, at which position the gear and rudder were 'amidships'. The forward cylinder was also arranged to bypass both sides of the piston when the steering wheel was amidships, thus permitting the centralizing springs to synchronize the rudder with the steering wheel.

The Brown Telemotor was of the inside-packed or piston type incorporating hydraulic fluid consisting of water mixed with 30 per cent glycerin to prevent it from freezing. Any mixture over 60 per cent was too thick to operate properly, but a mixture of 30 per cent had a safe working temperature down to 10° Fahrenheit. The piston in each cylinder was rendered pressure-tight by means of leather piston rings.

The Brown Telemotor also had the advantage of giving increased resistance to turning the wheel with increasing rudder angle. When pulling the wheel around, it became noticeably stiffer until it was hard over, so that the helmsman felt the amount of helm he was giving the ship much in the same way as in steering by hand with the antiquated winding drum and ropes or chains.

The Navigating Bridge was fitted with a standard wheel stand mechanically connected to the Brown Telemotor transmitter in the Wheelhouse. The Navigating Bridge wheel was typically used when the ship was under direction of a pilot or in any other situations where frequent helm orders were necessary. The Navigating Bridge wheel stand was connected to the Telemotor by a horizontal overhead brass drive shaft that ran vertically up the forward bulkhead to a gearbox, aft along the ceiling through a plummer block, and into the Brown's Patent Telemotor located in the Wheelhouse. To allow the ship to be steered directly from the Wheelhouse, the shafting from the Navigating Bridge wheel stand was disengaged from the telemotor while simultaneously engaging the wheel in the Wheelhouse by moving a clutch lever located on the change-over gearbox incorporated into the telemotor pedestal.

The ship could also be maneuvered from the Docking Bridge through the use of the wheel at that location; however, this wheel was considered an auxiliary wheel and for use only during docking or emergencies. The Docking Bridge wheel was not part of the Brown Telemotor system and was mechanically coupled to the valve linkage controlling the steering engines on the Shelter Deck (C) below.



STEERING CONTROL PEDESTAL AND SHAFT COUPLINGS

Fig. 22-39 **Pedestal Diagram** – A diagram showing the internal features of a common wheel pedestal of the era. With only slight differences, the markings on the top of the wheel shown here were the same as on *Titanic*. The pedestal on the Navigating Bridge had a shaft extending from the top that linked with the telemotor aft in the Wheelhouse. This shaft was disengaged when the ship was being steered from the Wheelhouse (typically outside pilotage waters). Both the Navigating Bridge and the Docking Bridge wheel pedestals have been raised from *Titanic*'s wreck. (The wheel in the Wheelhouse was not connected to a pedestal of this type; instead, an A-frame supported a shaft as it passed from the wheel through the binnacle and into the telemotor.)

In this diagram, the wheel was mounted on a horizontal shaft, *A*, within the vertical pedestal, *B*. Shaft *A* rotated the vertical shaft, *C*, through bevel gears *DK* and *DD*. After exiting the pedestal, the shafting was continued by vertical and horizontal lengths, connected by bevel wheels, or Hooke's joints, to the steering gear flat where it was coupled through clutches with the differential valve spindles.

The number of turns of the wheel was limited to four revolutions in either direction from amidships to extreme helm, at which point the wheel was said to be 'hard over.' Shaft *A* was machined with a specially pitched thread, *E*; turning the steering wheel revolved the threaded shaft within a threaded bore in the limit nut, *F*, which was moved along the shaft but did not revolve with it. A projection was made on the bevel gear *DK* at *K*, and on the collar *G*; *DK* and collar *G*, which were keyed to shaft *A* and revolved with it. At the extreme points of the travel allowed, opposing projections on the limit nut *F* came in contact with the projections on *DK* and *G*, preventing further rotation of the wheel.

A toothed rack *R*, made integral with the limit nut *F*, moved with the nut, rotating the spur gear to which a pointer, *P*, was attached; the pointer was located outside and on top of the pedestal. A dial engraved into the top cover of the pedestal showed the amount of helm imparted to the controlling gear. This pointer did not necessarily show the exact position of the rudder or tiller in connection with it; this was shown by the helm indicator, which was actuated by the rudder head.

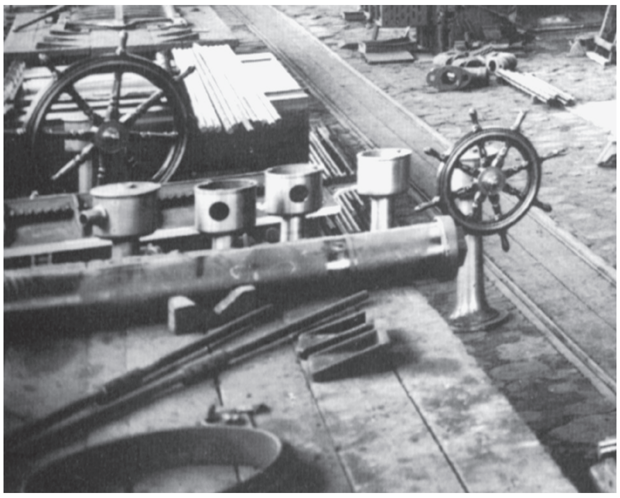


Fig. 22-40 Wheel Pedestals – Wheel pedestals await assembly at the Fitters' Shop at Harland & Wolff. *(H&W/Authors' collection)*

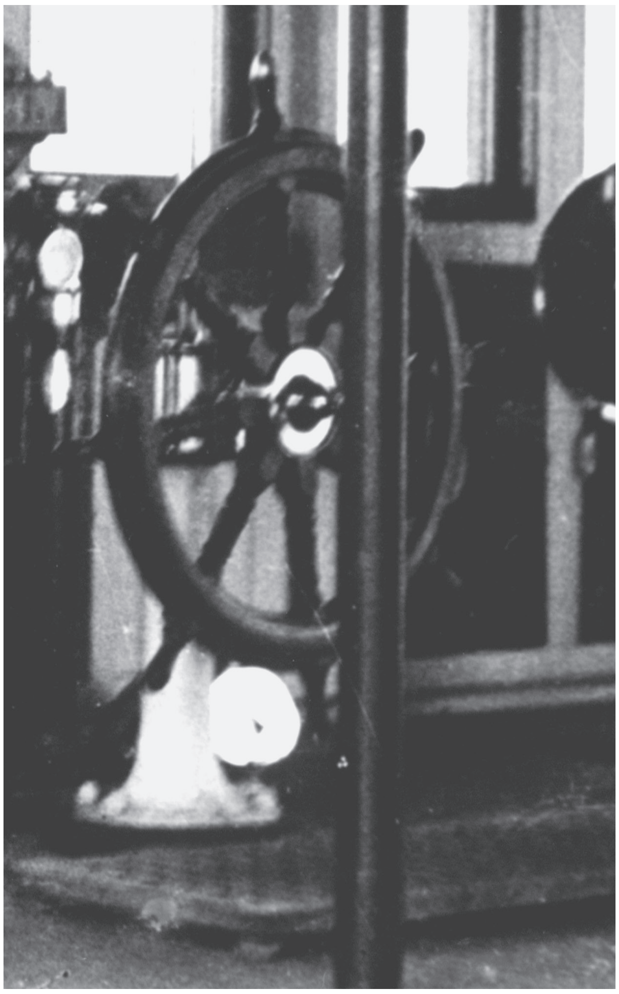
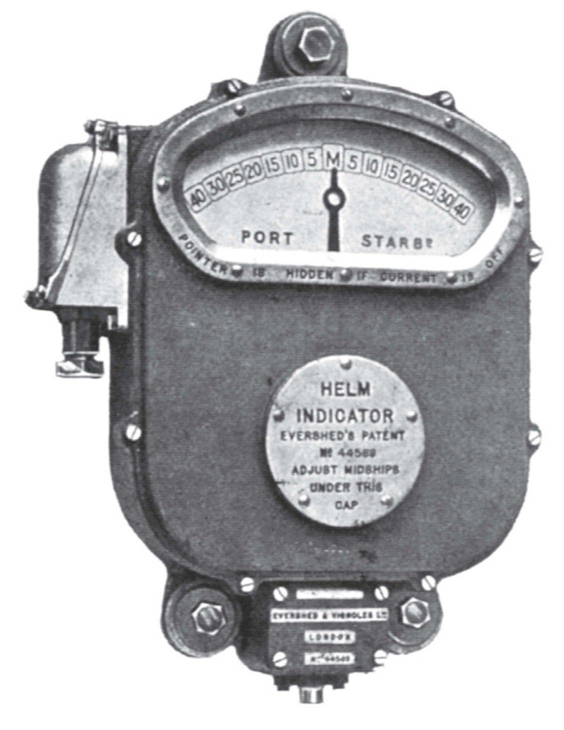


Fig. 22-41 ***Olympic*'s Navigating Bridge Wheel and Pedestal** – The wheel and pedestal on *Olympic*'s Navigating Bridge. *(Father Browne photograph/Authors' collection)*



40 30 25 20 15 10 5 M 5 10 15 20 25 30 40
PORT
STARBD
POINTER IS HIDDEN IF CURRENT IS OFF
HELM
INDICATOR
EVERSHED'S PATENT
No 44569
ADJUST MIDSHIPS
UNDER THIS
CAP
EVERSHED & VIGNOLES LTD
LONDON

Fig. 22-42 **Electric Helm Indicator.**

Helm indicator and course indicator

An electric helm indicator was mounted on the forward bulkhead of the Navigating Bridge above the binnacle, and in the Wheelhouse directly above the wheel. The transmitter was in the steering engine space aft. This device showed the precise location of the rudder at any moment with the use of a needle indicating degrees to port or starboard. In the event that power was interrupted within the helm indicator system, the indicator needle moved fully to one side and out of sight, giving visual indication of the trouble. The device was made by Evershed & Vignoles Ltd, London.

Just below the helm indicator was a course indicator box. This wooden fitment had three separate multi-sided blocks on which numbers were printed; these were turned to display the appropriate numbers and inserted to display the course to steer by. The front of the device had three windows which allowed the Quartermaster to view the course which was indicated by the inserted blocks. By means of this indicator, the course to be steered was always displayed in clear view. In the Wheelhouse, the course indicator was located on the forward side of the wheel and was illuminated at night.

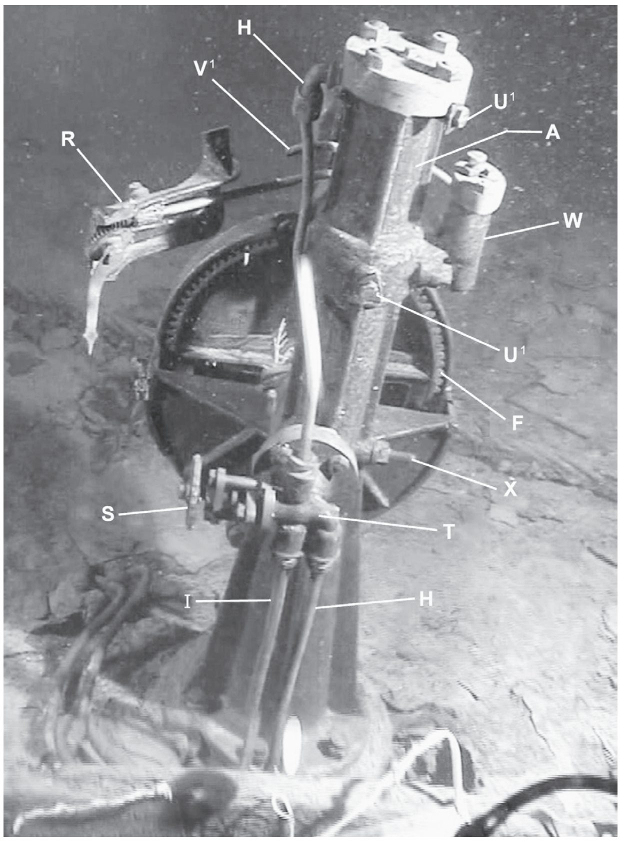

H
V^1
R
U^1
A
W
U^1
F
X
S
T
I
H

Fig. 22-43 **Telemotor.** *(Steve Rigby collection)*

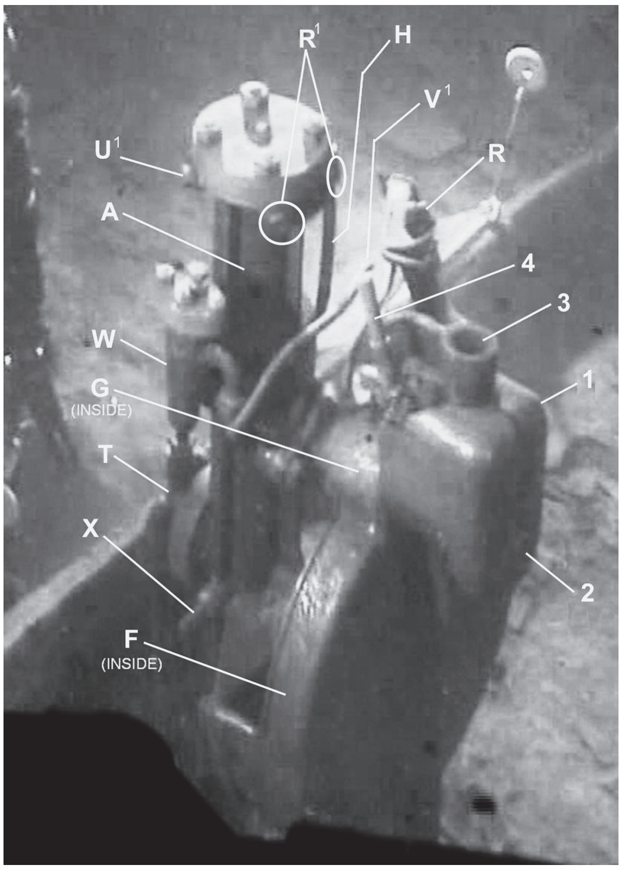

R^1
H
V^1
U^1
R
A
4
3
W
1
G
(INSIDE)
T
X
2
F
(INSIDE)

Fig. 22-44 **Telemotor**. *(Steve Rigby collection)*

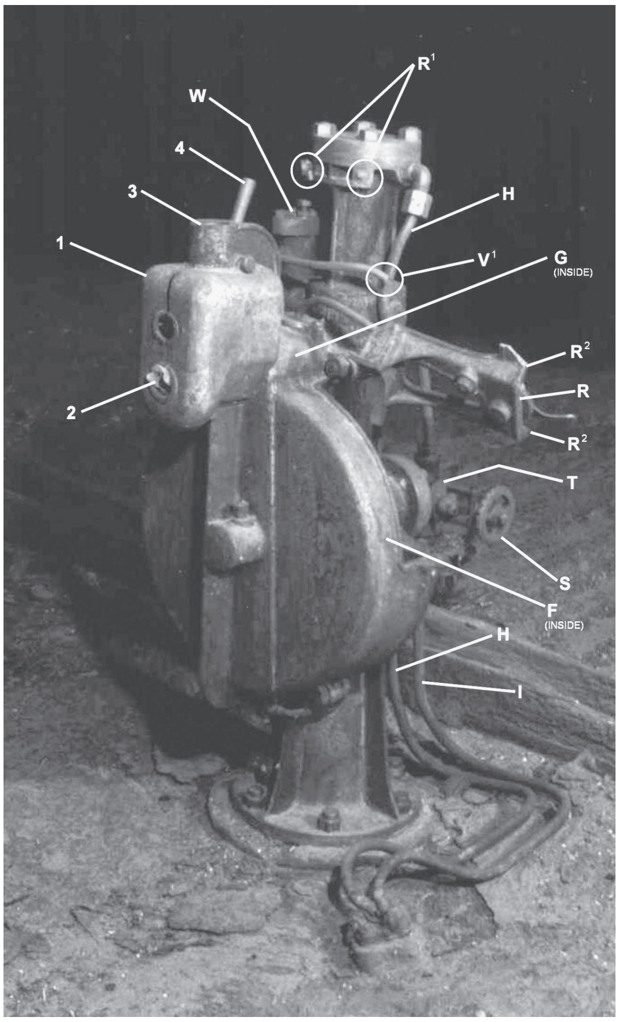

R^1
W
4
3
H
1
V^1
G
(INSIDE)
R^2
R
2
R^2
T
S
F
(INSIDE)
H
I

Fig. 22-45 **Telemotor**. *(Bernard Funk collection)*

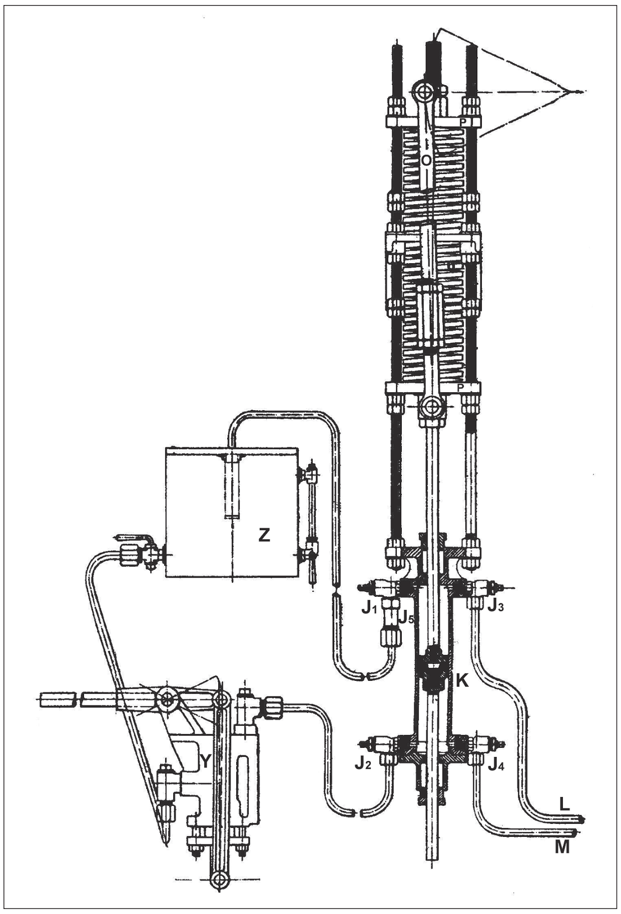


Fig. 22-46 **After Cylinder.** *(Scott Andrews collection)*

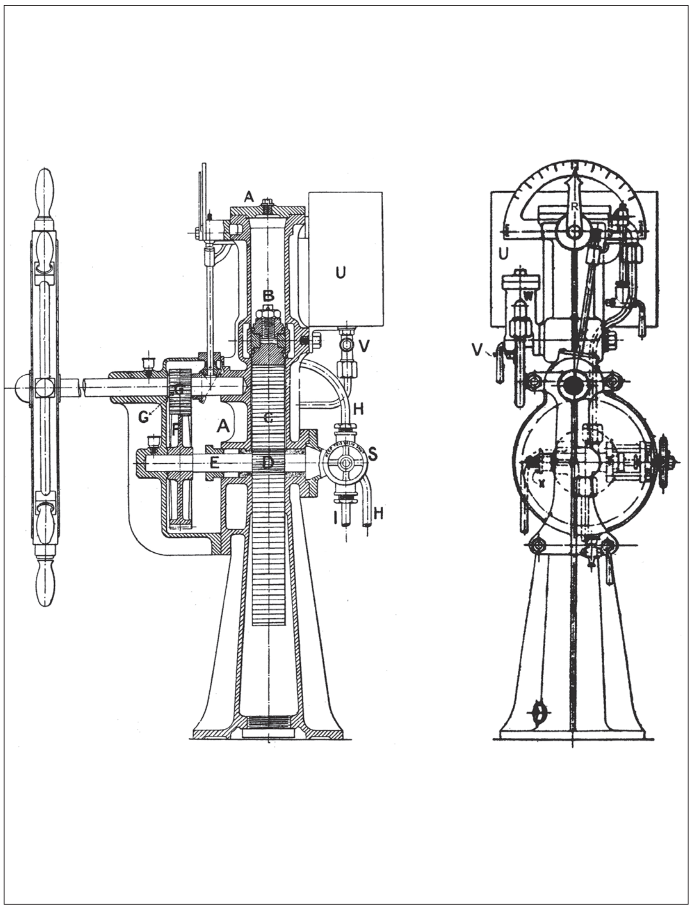


Fig. 22-47 **Telemotor.** *(Scott Andrews collection)*

In this series of images from *Titanic*'s wreck, the parts of the telemotor have been identified in conjunction with two drawings illustrating the component parts:

A	Hydraulic cylinder ('master')
B	Piston
C	Piston Rack
D	Pinion
E	Main shaft
F	Spur wheel
G	Pinion and hand wheel shaft
H	Hydraulic fluid pipe (from top of cylinder)
I	Hydraulic fluid pipe (from bottom of cylinder)
J^1, J^2	Valves to shut off system from hand-operated charging pump
J^3, J^4	Valves to shut off system from after cylinder *K* during seal replacement, etc.
J^5	Spring-loaded valve to prevent drain-back or siphoning of fluid during system charging
K	Receiving cylinder ('slave')
L, M	Hydraulic fluid pipes from telemotor forward
N	Receiving cylinder piston
O	Connecting link
P	Receiving cylinder piston rod crossheads
Q	Compression springs (causes piston *N* to always return to center position)
R	Helm position indicator (broken off and twisted around 180° on wreck)
R^1	Broken mountings for *R*
R^2	Broken-off bottom edge of indicator quadrant
S	Stop valve hand wheel
T	Stop valve (allows free communication between top and bottom of *B*, telemotor piston, when open; used for quick adjustment of the indicator position without affecting the rudder, and for disabling the telemotor when in port; kept closed at all other times)
U	Hydraulic fluid reservoir/expansion tank (broken off and missing from wreck)
U^1	Broken mountings for *U*
V	Shut-off cock for *U* (missing from wreck; attached to *U*; and to pipe between *U* and *W* at V^1)
V^1	Reservoir tank end of hydraulic fluid pipe (this pipe originally ran from the bottom of tank *U* on the back side of the telemotor, and passed beneath *W* to the fitting on the front side of *W*; it is now broken off from *V*, and is twisted around and across the front side)
W.	Inlet/Relief valve box (automatic valves to accommodate the expansion and contraction of the hydraulic fluid within the pipes due to changes in temperature. Fluid is either expelled into, or drawn out of tank *U* as required)
X	Screw plug (When replacing seals, this plug was removed and reinstalled with the pin facing inward; this locked the rack in place to maintained its central position until the shaft and pinion were replaced)
Y	Hand-operated pump for charging up the system
Z	Charging pump reservoir tank
1	Change-over gearbox
2	Wheelhouse helm shaft (broken off)
3	Support bearing, for overhead shaft to Bridge helm (shaft pulled free)
4	Wheelhouse helm/Bridge helm change-over lever

Steering gear

The steering gear was situated at the after end of the Shelter Deck (C) under the Poop Deck. Providing power to move the steering gear was a pair of steam engines. The need for steam-generated power here was inarguable; no steering mechanism relying on hand power, regardless of how much mechanical advantage was built into the system, would suffice on a ship of *Titanic*'s size. *Titanic*'s rudder weighed 101¼ tons, in addition to which a rudder is moved side to side by applying a rotational power to the shaft, which presents no mechanical advantage. Add to this the force exerted by the waterflow against the rudder when the ship was in motion, and the need for mechanical power is evident.

Titanic's steering gear was of the well-known Wilson-Pirrie type, made by Harland & Wolff, and consisted of a spring quadrant and tiller on the rudder-head worked through wheel-and-pinion and bevel gearing by either of two sets of steam engines. Either engine sufficed for the working of the gear, the other being a standby.

The mechanism by which the rudder post was pivoted was the 'steering quadrant'. The name 'quadrant' comes from its shape, which is close to one-quarter of a circle. Gear teeth on the outer periphery of the quadrant meshed with those on the steering engine engaged to it; and depending on the direction the gears turned, the rudder moved either to the right or to the left. The quadrant was not directly connected to the rudder head, for to do so would have subjected the steering engines and steering gear to shocks and stress that they could not absorb. Instead, the working tiller consisted of two forged arms, one arm being placed at the center of each half of the quadrant. The tiller arms were keyed to the rudder-head, and were tied together by a strong wrought-steel tie bar. The quadrant arms were connected to the tiller arms by means of heavy spring links which absorbed any shocks. A spare tiller, arranged to come into operation only if the connection between the quadrant and working tiller was disabled, was placed immediately above the quadrant. This tiller could also be worked by the warping capstans on the same deck should the whole gear be disabled.

Each steam engine was of the three-crank vertical type. The engines had inverted direct-acting cylinders, each 17in diameter by 18in stroke, which took steam at a pressure of 100psi. Piston steam valves had been adopted, and worked directly from the crankshaft by means of eccentrics.

The cylinders of each engine were supported at the front by three wrought-steel columns, and at the back by three iron columns, two of the latter also forming supports for the intermediate shaft connecting the spur and bevel gears. Each engine was arranged on a sliding bed with adjusting screws so that it could be quickly put into or out of engagement with the quadrant when it was desired to change from one engine to the other.

The crankshaft of each engine was provided with a spur-pinion, which drove a spur-wheel on the intermediate shaft, carried on the back columns of the engine. This intermediate shaft was connected by bevel gearing to a vertical shaft, which in turn meshed with the quadrant by means of a manganese-bronze pinion situated above the bevel gearing. The spur and bevel gear were of the Citröen type, made of cast steel throughout, and had machine-cut helical teeth of herring-bone shape, which experience had shown to be the most suitable form for minimum wear when the gears had to transmit power in either direction, as was the case with a steering engine.

The sizes of the spur wheels were as follows: pitch circle diameters, 14½ and 69¾in; number of teeth, eighteen and eighty-seven; pitch, about 2½in; and width of face, 9½in. The pitch was given approximately as the Citröen gears were not made to standard pitches. Their noiseless running was mainly obtained through a total absence of backlash, and this could only be achieved by calculating the exact pitch according to given diameters and a fixed number of teeth. For this reason a special cutter was made for each set of gearing. The sizes of the bevel wheels were: pitch circle diameters, 5ft 10½in and 2ft 0½in; number of teeth, nineteen and five; pitch, about 4¼in; width of face, 11in. The teeth on both sides of the face were shrouded to the pitch line, and the total width over the shrouds was 14in. The weight of each bevel wheel was 1 ton 16cwt, and each spur wheel weighed 1 ton 6cwt. The spur pinion weighed about 5cwt, and the bevel pinion about 9cwt. The quadrant and the pinion on the vertical shaft had machine-cut involute teeth.

As noted previously, the steering gear was controlled from the Wheelhouse by a Brown Telemotor and from the Docking Bridge aft by mechanical means. The telemotor cylinders were placed near the steering engines and were connected by levers and shafting to the steam control valves on the engines. The control valve on each engine was fitted with an economic valve of Brown's type, which shut off the steam automatically when the engine was at rest, and so prevented the leakage of steam into the cylinders.

TELEGRAPHS

Engine and steering telegraphs

Located on the Navigating Bridge, the Docking Bridge and in the Reciprocating Engine Room were a series of telegraphs. These devices were made by J.W. Ray & Co., Liverpool, and were each fitted with double glass dials measuring 20in in diameter on the Navigating Bridge and Docking Bridge and 24in in diameter in the Engine Room.[15] Each telegraph stood approximately 49in tall as measured to the outside of the dial flange at its uppermost point and had two handles, one on each side of the dial drum. Each drum was approximately 15¾in wide from dial face to dial face, and approximately 21in in diameter. The handles on either side of each dial drum worked independently of each other and were not connected. Five telegraphs were located on the Navigating Bridge, three on the port side and two on the starboard side. Three of the telegraphs – the outermost one on each side, plus the one immediately to port of the wheel – were called 'engine order telegraphs', and were linked to indicator telegraphs in the Engine Room, instruments which were used to receive and acknowledge these orders. Each engine order telegraph was fitted so that its starboard handle sent orders for the starboard reciprocating engine, and the port handle, for the port engine. The indications on the dials, corresponding to the commands that could be given via these telegraphs, were DEAD SLOW, SLOW, HALF ASTERN and FULL ASTERN; DEAD SLOW, SLOW, HALF AHEAD and FULL AHEAD; STOP; and STAND BY ASTERN and STAND BY AHEAD. The 'Stand By' commands can be best described as preparatory commands; they alerted the Engine Room to be prepared to receive orders.

The outermost (outboard) telegraphs on each side were the main engine telegraphs, and were linked to each other through a set of cross-shafts and sprockets housed within the box-like enclosure situated overhead on A Deck beneath the Bridge. If the handle for the starboard reciprocating engine was moved on the main engine telegraph on one side of the Bridge, the same command would show on the starboard handle of the corresponding telegraph on the opposite side of the Bridge. This eliminated the need to run across the Bridge to access the commands for port and starboard engines, as commands for both engines could conveniently be sent from the telegraph on either side. The two main engine telegraphs were connected to two 24in indicator telegraphs in the Engine Room, one for the starboard reciprocating engine and one for the port reciprocating engine.

The third engine order telegraph, known as the emergency engine telegraph, was located immediately to port of the wheel[16] and was connected to two additional indicator telegraphs that duplicated the function of the two indicators referred to above. Because this telegraph served as an emergency back-up in case the linkage for the main telegraphs failed, it was connected to its indicator telegraphs through an entirely independent linkage. Like its counterparts located to either side of the Bridge, the emergency engine telegraph was also designed with two independent handles – one for each reciprocating engine respectively.

The three main engine order telegraphs were made of brass with glass indicator dials. They were double-dialed, with an independent order-transmission handle and automatic reply indicator located on each side. The various engine commands were marked inside the dial; the handle on each side that communicated the orders was constructed such that the handle was positioned directly in line with the order desired. Rotating around the dial inside of and operating independently of the handle mechanism was a brass pointer that would indicate the acknowledgement of the order from the Engine Room. When an order was given to the Engine Room, the officer on the Bridge moved the handle to the order he wished to transmit; this caused the matching pointer on the telegraph in the Engine Room to move to the order transmitted. The engineering officer in the Engine Room would then move his handle to match up with the pointer, thereby acknowledging the order. On the Bridge, the officer would see the pointer on his telegraph move in line with the order transmitted. At the same time, at each end a mechanism inside tripped a bell as the handle was rotated about the dial, and whenever an acknowledgement caused the pointer to rotate, so that attention was readily drawn to an order given or acknowledged.[17]

Fitted to each of the two outboard main engine telegraphs, facing aft where it could be clearly seen from any point on the Bridge, was a patent automatic direction indicator that showed the direction that each engine was turning. Each indicator consisted of a clear glass dial with a pair of pointers, one colored red for the port engine and the other green for the starboard engine. The pointer for each engine indicated whether it was turning forward, ahead, or stopped. As one of these direction indicator dials was fitted to each of the outboard main engine telegraphs, the actions of both reciprocating engines could be observed from either side of the Bridge. Their advantage was in that they indicated what each of the two main reciprocating engines were actually doing at any given time, not just the acknowledgement of the order from the Engine Room; thus, the officer on the Bridge could verify the execution of the orders he had transmitted. These devices were only on the outboard port and starboard two main engine telegraphs.

The two remaining telegraphs, one immediately to starboard of the wheel and the central one to port of the wheel, were for communicating with the Docking Bridge on the Poop Deck. They were of the same make and

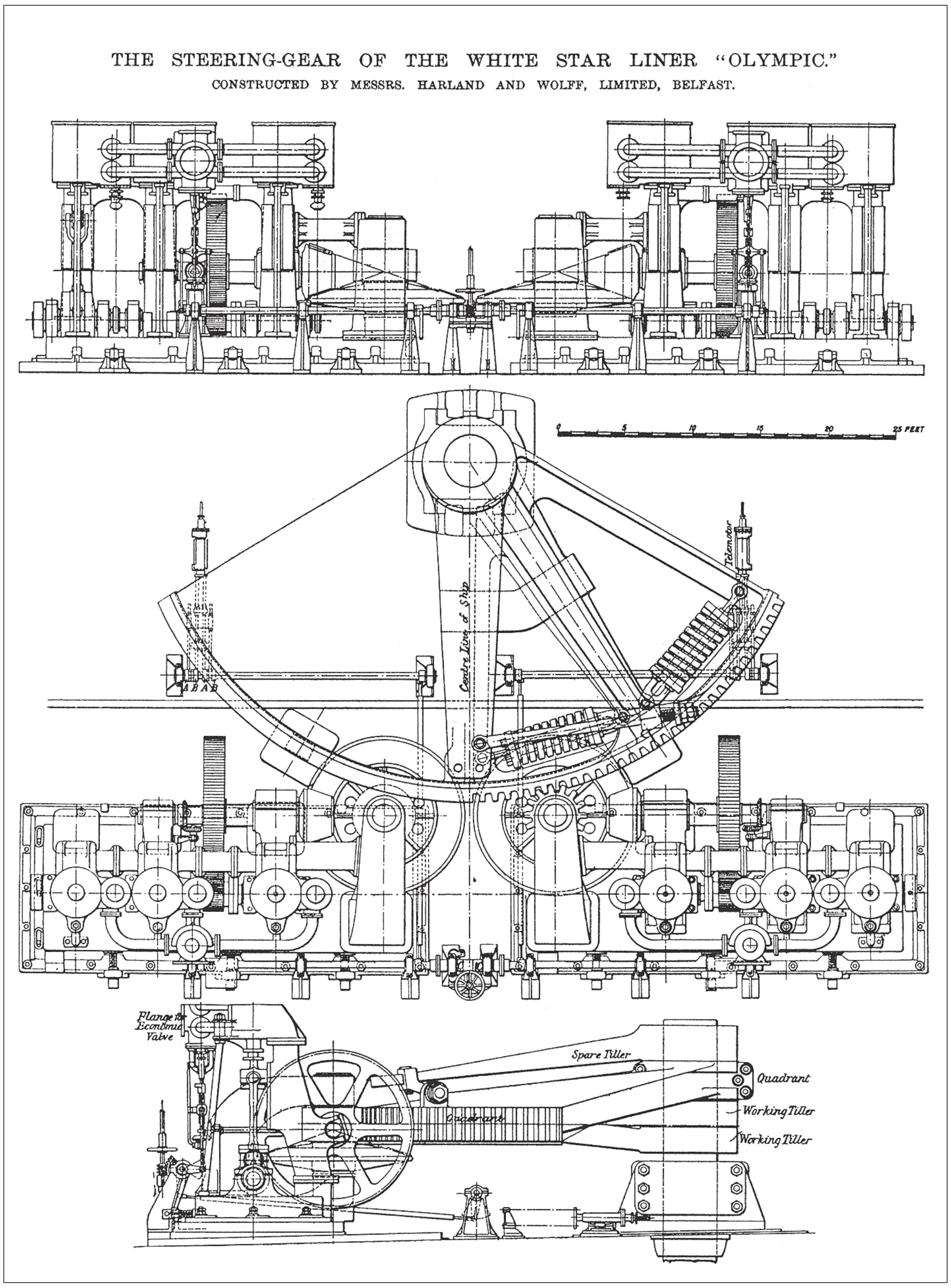

THE STEERING-GEAR OF THE WHITE STAR LINER "OLYMPIC."
CONSTRUCTED BY MESSRS. HARLAND AND WOLFF, LIMITED, BELFAST.
0 5 10 15 20 25 FEET
Telemotor
Centre Line of Ship
A B A B
Flange for Economic Valve
Spare Tiller
Quadrant
Working Tiller
Working Tiller
Quadrant

Fig. 22-48 **Steering Gear Diagram**. *(*The Shipbuilder/ *Authors' collection)*

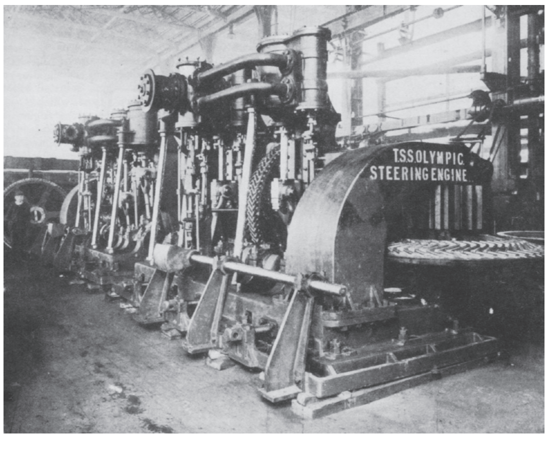

T.S.S. OLYMPIC
STEERING ENGINE

Fig. 22-49 **Steering Gear** – *Olympic*'s steering gear and steering engines in the shop at Harland & Wolff. *(*The Shipbuilder/*Authors' collection)*

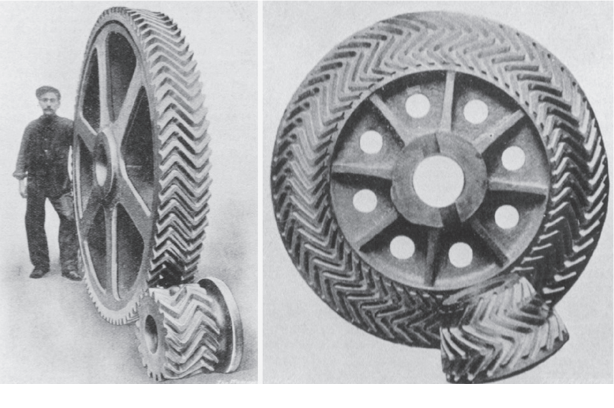


Fig. 22-50 **Citroën wheels** – At left, a Citroën spur wheel and pinion from *Olympic*'s steering gear assembly. At right, a Citroën bevel wheel and pinion from the same assembly. *(*The Engineer/ *Authors' collection)*

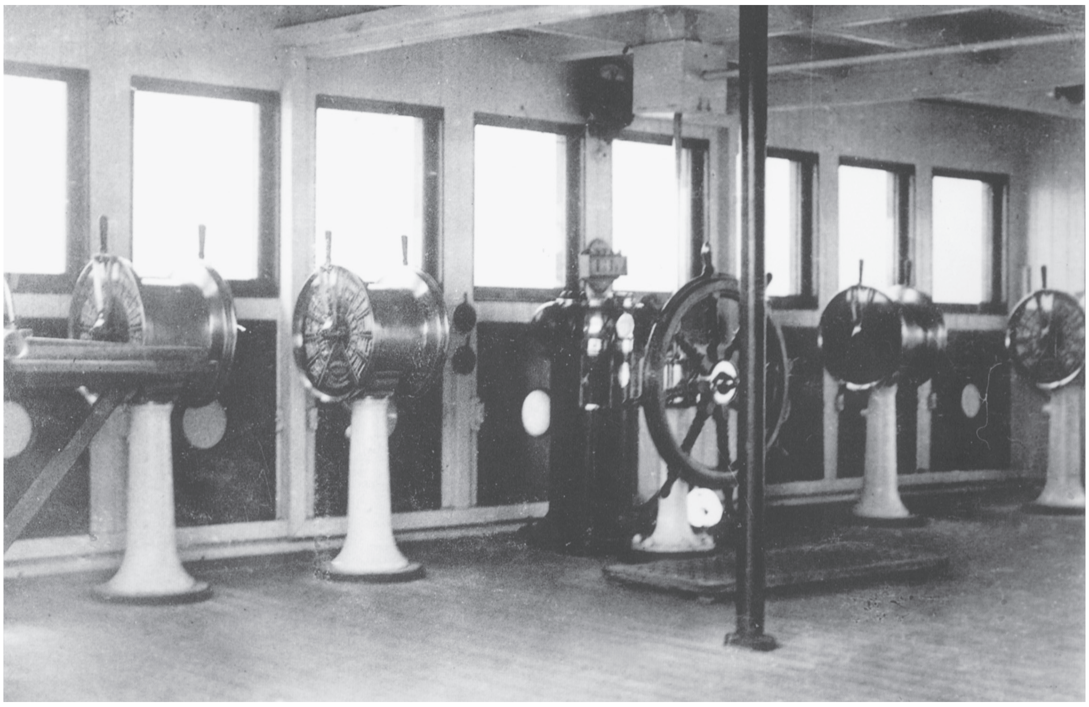


Fig. 22-51 ***Olympic*'s Bridge** – *Olympic*'s Navigating Bridge as photographed shortly after the *Titanic* disaster by Frank Browne. This is the only known photograph taken inside *Olympic*'s Bridge. Four of the telegraphs are visible here, with the port main engine telegraph just out of sight to the left. The wheel and pedestal are in the middle with shafting seen extending to the deck head and running aft to the Wheelhouse. In front of the pedestal is the Kelvin binnacle with the brass cover over the compass removed and lying to the right on the deck. Mounted between the windows in line with the top of the binnacle is a wooden course indication box containing three separate multi-sided blocks, visible through the three panes facing the quartermaster. To change the course displayed, these blocks were removed, turned and reinserted to indicate the new course numbers to steer by. At the deck head above the course indication box is the helm indicator showing the position of the rudder as transmitted from the steering machinery on the Shelter Deck (C) aft. The two round devices seen under the window on the left of the binnacle are a set of whistle controllers. Also seen directly above the center window is a small lanyard for the ship's bell. *(Father Browne photograph/Authors' collection)*

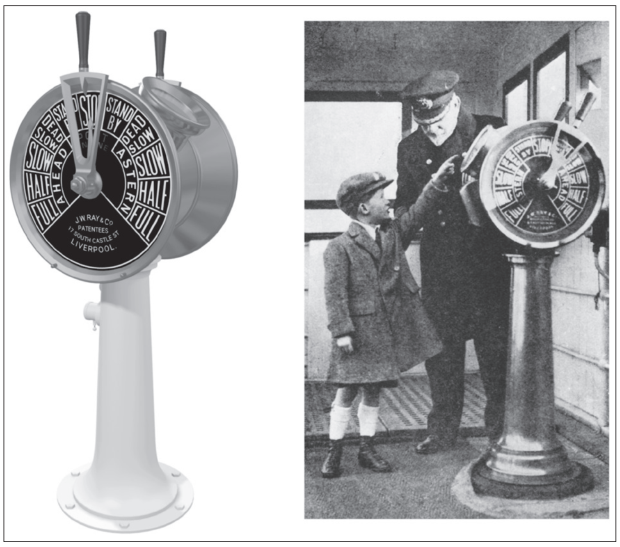


Fig. 22-52 **Engine Order Telegraph** – At left, an artist's rendering of one of *Titanic*'s main engine telegraphs. At right, a period photo that has commonly been identified as Captain Smith on *Olympic*. While this may possibly be Captain Smith, the ship is definitely not *Olympic*, nor is it even an *Olympic*-class liner. (The ship itself has not even been positively identified as a White Star Line ship.) In any case, the engine order telegraph is very similar to that used on the *Olympic*-class ships. *(Illustration by Michael McMillan; photograph from authors' collection)*

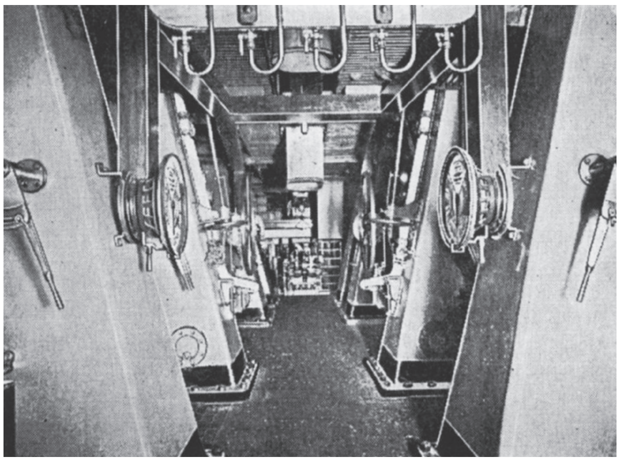


Fig. 22-53 **Engine Room Telegraph** – The engine order telegraphs from the Navigating Bridge would relay commands to corresponding indicator/reply telegraphs at the Starting Platform of the Reciprocating Engine Room. The Starting Platform seen in this image is from the Harland & Wolff-built *Nieuw Amsterdam*. The telegraphs are mounted above deck level to the left and right. *(Scott Andrews collection)*

design as those discussed above. One was an engine order telegraph linked to a similar telegraph on the Docking Bridge. If the ship was being conned from the Docking Bridge instead of the Navigating Bridge – for instance, when backing the ship from her pier – this would be used to relay engine commands to the Navigating Bridge; and the Navigating Bridge, in turn, would relay the command to the Engine Room via the main engine telegraphs. The second telegraph between the Navigating Bridge and the Docking Bridge was unique in that it did a double duty. The markings on the inner half of the dial on each side served a different purpose from the markings on the outer half; one set of markings pertained to helm commands and the other set pertained to line-handling commands. Most frequently, it was used for the latter when docking. When being used as a docking telegraph, on one side of the telegraph *Titanic*'s officers could communicate the commands from the Navigating Bridge of 'SLACK AWAY STBD', 'HOLD ON STBD', 'LET GO TUG', 'LET GO ALL AFT', and 'SET OFF NIGHT SIGNALS'. In addition to acknowledging the aforementioned commands, messages could be sent from the Docking Bridge to the Navigating Bridge: 'ALL CLEAR STBD' and 'NOT CLEAR STBD'. The equivalent port side commands and messages could be sent and received on the opposite side of the telegraph; the handles on the port and starboard sides were not connected and functioned independently. The markings on the inner dial on each side, corresponding to helm commands, would be used if a mechanical failure rendered the steering on the Bridge inoperative such that the ship had to be steered from the Docking Bridge. In this case, the Navigating Bridge would need to send steering commands aft. On the dial of this type of telegraph, these would typically be marked in degrees of helm either port or starboard, in increments of five.

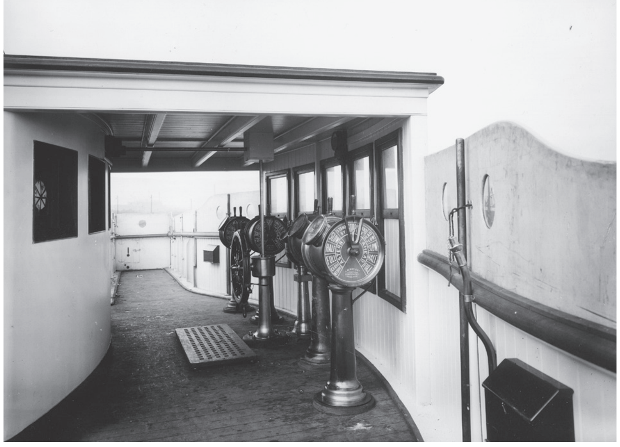


Fig. 22-56 **Navigating Bridge of *Adriatic*** – The main engine order telegraph in this image, *c.* 1907, includes the command 'Close Watertight Doors,' a command which was determined to be redundant and so was omitted from *Titanic*'s engine order telegraphs. Notice also the wheel with its brass pedestal and brass binnacle in front. This bridge, as well as that of the *Oceanic* (below left), is shown here to illustrate a navigating bridge design that Harland & Wolff used repeatedly over the years to the apparent satisfaction of their clients. This design has been criticized in modern times as not being conducive for good communication between the officers and crewmen on the bridge. However, although these bridges may not satisfy today's standards, they worked well for ships at the turn of the twentieth century, and were considered efficient in their time. One should always be careful when comparing the standards and practices of ocean liners of the early 1900s against modern-day maritime standards, especially those of the US Navy. *(H&W/Authors' collection)*

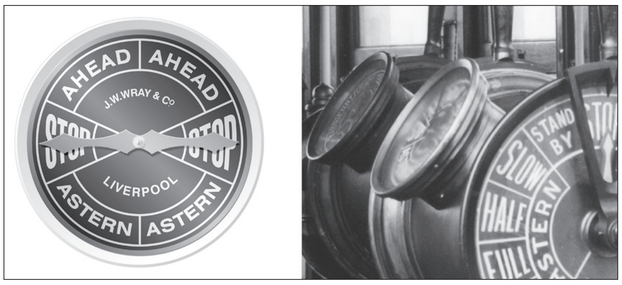


Fig. 22-54 **Engine Direction Indicator Dial** – At left, an artist's impression of one of *Titanic*'s main engine direction indicator dials as based on historical photographs of period J. W. Ray telegraphs. At right, indicator dials of the same type as seen on the White Star Line's Adriatic. *(Illustration by Jason Dedonno; image from authors' collection)*

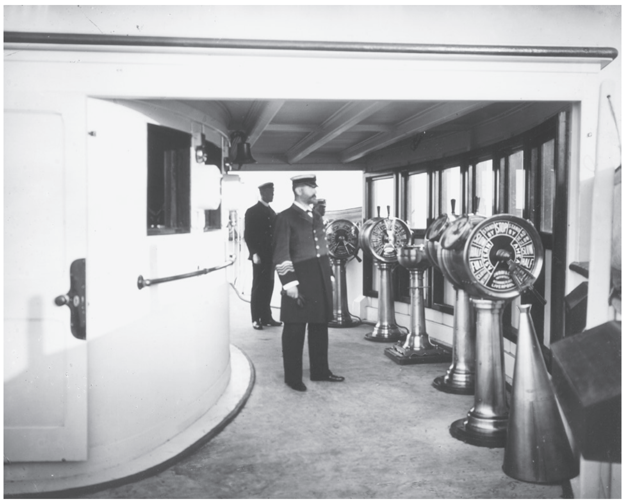


Fig. 22-55 **Bridge of the *Oceanic*** – The Bridge of the *Oceanic*, August 1899. One of the engine order telegraphs is seen in the foreground with the handles in the 'Full Ahead' position. Notice the megaphone and the binocular box. In the center of the picture is Captain John G. Cameron. *(H&W/Authors' collection)*

Inside the dial case of each telegraph was a pair of chain pulleys for each dial, with each one keyed onto the axles that carried the respective handles and the pointers. One chain pulley of the pair was for the signal from the Bridge while the other was for the reply from the receiving location. Around these pulleys were laid chains that engaged the pockets within the pulleys; both ends of this chain ran for some length down the pillar of the telegraph, at which point the ends were connected to two heavy copper wires which led to the telegraph at the opposite end. Here, the ends of wires were again connected to a chain laid around a corresponding chain pulley. Some appreciation can be gained for the complexity of this system when considering that two pairs of cables were required – one for transmitting commands, the other for transmitting acknowledgment of the order – for every telegraph dial on the Bridge.

In the case of the two main engine telegraphs, the internal arrangements were even more complex because, in addition to the two pairs of chains required for the port and starboard engine command dials, an additional pair of chains was required to move the two pointers of the automatic direction indicators. Internally, the twelve ends of these chains were organized and guided by six pairs of small sheaves contained within the squared-off casting joining the dial drum to the top of the pillar. From here, the chains passed downwards through the deck, where they were then led over chain pulleys keyed to the cross-shafts which coupled the duplexed controls and indicators of the main engine telegraphs. Keyed to each of these shafts was a third cable pulley located approximately amidships, around which were led the chains connected to the forward ends of the copper wire pairs leading to and from the Engine Room.

It was essential that when an order was given on any of the Bridge telegraphs the same order was received at the receiving station, and that the acknowledgement received on the Bridge was the same as the one sent in reply. To facilitate the proper synchronization of the telegraphs transmitting and receiving telegraphs, tightening screws were fitted between the chain and the copper wire at each end. On each telegraph pedestal was a plate that was easily removed by taking out a few screws; this exposed the tightening screws by which the telegraph could be adjusted.

All of the principal moving portions of the telegraph gear throughout the runs to the Engine Room and Docking Bridge had an enclosed type of ball-bearing center, and all the sheaves in the leads were fitted with Ray's Patent phosphor-bronze ball-bearing pulleys 6in in diameter, the result being that, although there were a total of 312 of these sheaves fitted to the various bends throughout the pathways along which the wires ran, the friction was so minimal that the levers could be put over from 'FULL AHEAD' to 'FULL ASTERN' by the effort of only two fingers on the lever, and the time occupied in moving over the complete range of orders should not have been any more than two seconds.

Officers did need to be mindful, however, of the length and number of turns in the linkage, and were advised not to use excessive speed or force in the movement of the levers. One source cautioned officers to: 'at all times work the telegraph as easily as possible, and so lessen the chance of it carrying away.'[18]

An additional electric telegraph was supplied to monitor the working of the turbine engine. The turbine was put into service when the ship was running at half or full ahead, and this action could be observed on a small wall-mounted instrument within view of the officers on the Bridge.

Per White Star Line regulations, the telegraphs between the Bridge and Engine Room were to be tested each day at noon when at sea.

Boiler Room Order Telegraphs

A system of illuminated telegraphs was provided between the Starting Platform in the Reciprocating

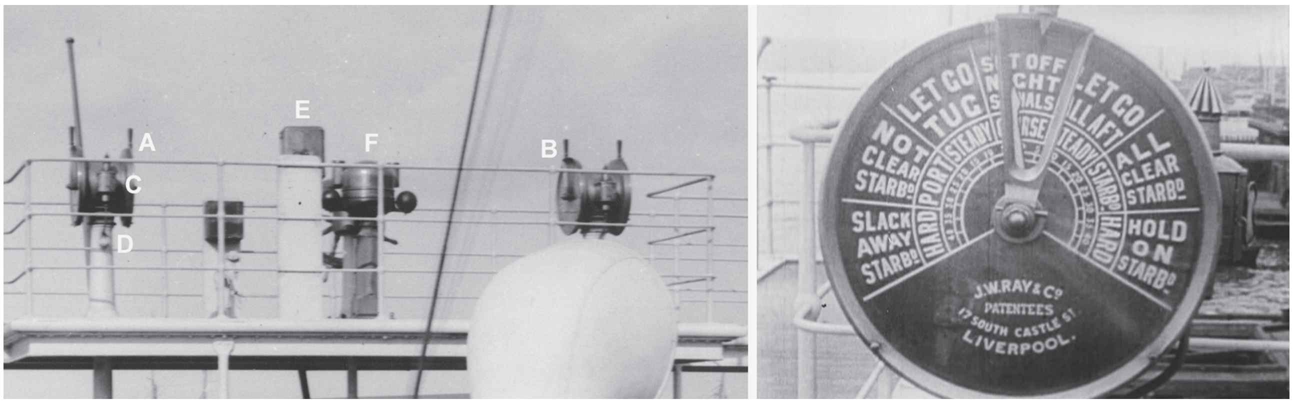


Fig. 22-57 **Docking Bridge Telegraphs on *Olympic*** – At left, in this image of *Olympic*'s Docking Bridge taken later in her career, the items and equipment seen here are: A – Engine order telegraph to Navigating Bridge; B – Combination steering and docking telegraph to Navigating Bridge; C – Oil lamp assembly with ventilation hood, for illuminating the dial inside in event of failure of the electric light bulb; D – Electric light switch for illuminating dial from inside; E – Telephone box; F – Brass Kelvin binnacle. At right, an enlarged image of the dial of the docking and steering telegraph.

Engine Room and the various boiler rooms to enable the Engineer on watch to communicate his orders to each stokehold. With eleven stokeholds to control, the foremost of which was 320ft from the Engine Room, the necessity for such an arrangement was evident. The transmitter and receivers had been supplied by Evershed & Vignoles Ltd. The same firm had also supplied a set of Kilroy's stoking indicators for each stokehold; these are described in Chapter 17 of this volume.

NAVIGATIONAL LIGHTING

Titanic's electric navigational lamps were manufactured by W. H. Allen & Co., Bedford. Harvie's copper oil lamps were supplied as emergency backups. As per regulation, the masthead lamp and sidelights were fitted with dioptric lenses to concentrate their light outwards in a horizontal plane. The specifications as to illumination, range, and mounting were set forth in the 'Rules of the Road'.[19] Emergency oil lamps were always on hand in case of power failure of any of these devices, and were usually stored in the Wheelhouse. As noted in Chapter 17 of this volume, the navigational lighting also had connections to the emergency dynamo circuits so that they could be supplied with power even in the event of failure of the main generating plant.

Masthead lamp(s)

Titanic had an electric masthead lamp mounted on the forward side of the foremast. It was approximately 10in x 11in in size, and mounted at a height of 102ft 6in above the Forecastle Deck. Under international maritime law it was to be a bright white light constructed so as to show an unbroken light over an arc of the horizon of twenty points of the compass (225°), fixed to throw the light ten points (112.5°) on each side of the vessel from right ahead to two points (22.5°) abaft the beam on either side and of such a character as to be visible at a distance of at least five miles. Under the 'Rules of the Road', this light was required to be displayed any time at night when a vessel was underway.[20]

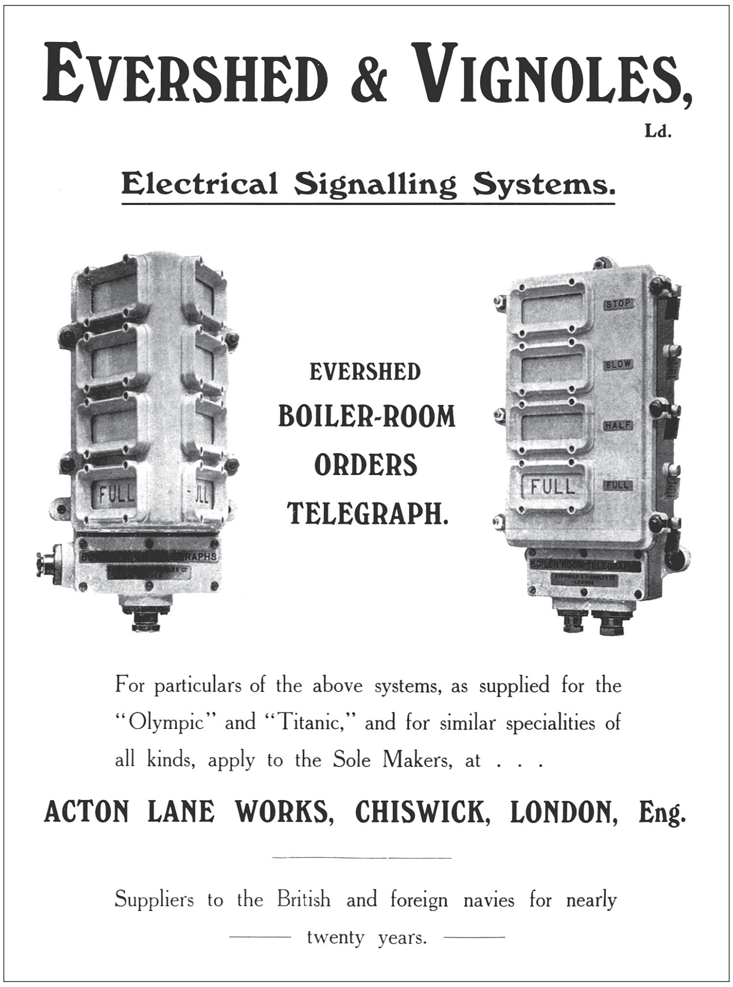
The lamp case was made of brass, and was attached to the masthead by means of two screw clips, one on each side. A door in the bottom gave access to a light bulb with two 16-candlepower filaments, which produced 32 candlepower collectively. In the event where one burned out, the other would remain lit until the bulb could be replaced. As with the Morse lamps discussed below, a dioptric lens of clear glass focused the light into a horizontal plane.

A steam vessel when under way could carry an additional white light aft (on the mainmast) similar in characteristics to the masthead light at the foremast. Both lights had to be placed in line with the keel, with the after light at least 15ft higher than the forward light. The vertical distance between these lights was required to be less than the horizontal distance. The two lights would, together, form a 'range'. This would indicate with far greater certainty the vessel's heading: when a large vessel was seen at distance at night, the lower light indicated the direction the vessel was heading, and the horizontal distance between them indicated its relative course – if the lights were directly in line with each other, the vessel was being seen head on, and if they were separated horizontally, it indicated that the vessel was being seen at some angle. It is uncertain whether or not *Titanic* ever displayed such a light, as neither the rigging plan nor photographs show any provisions for hoisting a lamp that would fulfill the requirements of the Rules. If one was in fact used, it would have almost certainly been an oil lamp. The existence of this lamp is supported by testimony from *Titanic* survivor Elizabeth Shutes, who stated in regards to *Titanic*'s final moments that 'only one tiny light was left – a powerless little spark, a lantern fastened to the mast'. Since this light remained lit after the rest of the ship went dark, it would have to have been an oil lamp.[21]

Sidelights

Mounted on the outboard sides of the Bridge wing cabs were electric sidelights,[22] red in color on the port side and green on the starboard side. Under the 'Rules' these were required to be constructed as to show an unbroken light over an arc of the horizon of ten points (112.5°) of the compass, so fixed as to throw the light from right ahead to two points (22.5°) abaft the beam, and of such a character as to be visible at a distance of at least two miles. They were also required to be screened in such a manner as to prevent them from being seen across the bow. These lamps were fitted at a distance of at least 3ft from the forward edge of the wing cabs to comply with this requirement; the boxes in which the lights were fitted also had a solid screen aft. The insides of the boxes were painted in colors corresponding to the lens of the lamp mounted on each side. A door was fitted in the sides of the wing cab bulkheads to provide access for servicing the lamps.

Additional information about the sidelights and electric masthead lamp can be found in Chapter 17 of this volume.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Suppliers to the British and foreign navies for nearly twenty years.

Fig. 22-58 **Boiler Room Orders Telegraph** – These telegraphs, installed in every stokehold, allowed the Engineer at the Starting Platform to communicate changes in speed to the Junior Engineering Officer on watch in every stokehold. This would be done in advance of the Bridge actually ringing down the change in revolutions, in order that the stokehold crew would know in advance whether they would need to increase or decrease the rate at which steam was being produced. *(*The Shipbuilder*/Authors' collection)*

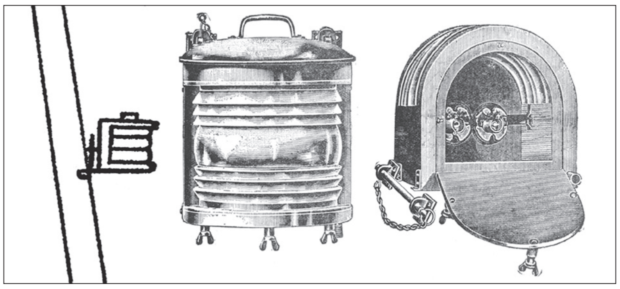


Fig. 22-59 **Masthead Lamp** – At left, an example of how a masthead lamp is indicated on a rigging plan. The simplified drawing actually shows the handle on the top of the cover, and the mounting posts at the back. The drawings at center and right are from an advertisement for a masthead lamp very similar to those on the *Olympic*-class ships; however, the sleeves that slid onto the mounting posts attached to the mast were located on the rear instead of on the sides as shown here. The electrical wire also connected through the back of the housing. The dioptric lens can be seen here, and should be instantly recognizable as this type of lens was, and still is, used to this day.

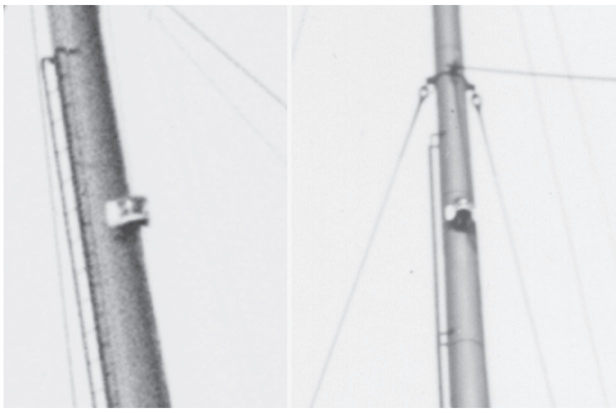


Fig. 22-60 **Masthead Lamps on *Olympic*** – Two views of *Olympic*'s masthead lamp. As one might imagine, it is difficult to get clear photographic images of this fitting because of its small size and location high on the mast. These images do, however, show the polished brass side shields that can be seen reflecting the sun. The side shields acted as shrouds to prevent the light from being seen further aft than two points (22.5°) abaft the beam on either side, as required by the 'Rules of the Road.' *(Both images from authors' collection)*

Anchor lights

A vessel was at anchor under the law when she was fixed by some means to the bottom, when she was made fast to a buoy which was itself fixed to the bottom, or when she was moored to a dock. The 'Rules of the Road' required steam-powered vessels to display lights of certain characteristics while at anchor so that other ships could readily identify that the vessel they were observing was not under way. The display of anchor lights was similar to the display of those displayed at the mastheads while under way, except that anchor lights were 'all-around' white lights, with the forward light higher, rather than lower, than the light displayed aft. For a forward anchor light, *Titanic* hoisted an oil lamp on one of her foremast stays at a height between 20ft and 40ft. At the stern, *Titanic* had an oil lamp hoisted along the backstay of the mainmast, suspended at a height approximately 15ft lower than that of the forward anchor light. A room reserved solely for the Lamp Trimmer's stores was located under the Forecastle Deck on the port side. The entrance was sealed by a Dutch door accessed from the forward Well Deck.

WHISTLES

Whistles and controllers

Titanic was fitted with a set of steam whistles on each of the four funnels. Though all four sets appeared to be genuine, in fact only those mounted on the Nos 1 and 2 Funnels were operational; the ones mounted on the Nos 3 and 4 Funnels were dummies made of a combination of cast iron parts and parts fabricated from non-ferrous metal alloys. The whistle set on the No.1 Funnel was generally activated with manually operated controls, while the whistle set on the No.2 Funnel was used for automatic operation. The activation and timing switches were mounted in the Navigating Bridge, in each Bridge wing cab, and in the Wheelhouse, allowing both the manual operation and automatic setting of the whistles from any of these locations.

Every self-propelled ship was required to have a whistle. In general, whistle signals were used to indicate the vessel's intent to other ships in close proximity when on converging courses, or when overtaking another ship. The meaning of the signal depended on the number and type of blasts, whether long or short.

The types of whistles in use in 1912 were the organ, dome, and siren. An organ whistle such as was mounted on the *Lusitania* gave a strong, loud note, but the range of audibility was not as great as that of the dome type fitted to *Titanic*. For a dome whistle, the note produced depended on the length of the vibrating column – i.e., the length of whistle – and the pressure of steam. Adjustment of the dome variety was accomplished by screwing the bell up or down on a central spindle. To obtain a greater volume of sound, three whistles of different notes (different dome sizes) were arranged on the same branch piece, with a common control valve.

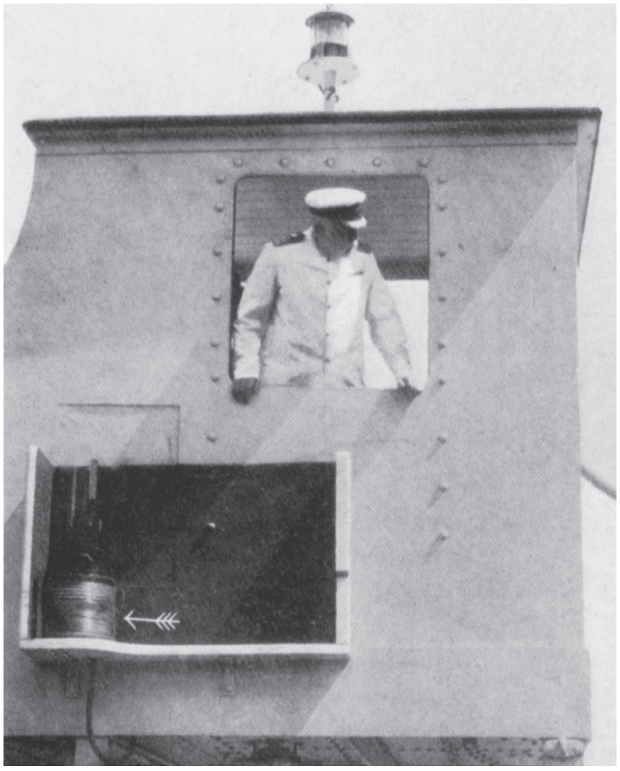
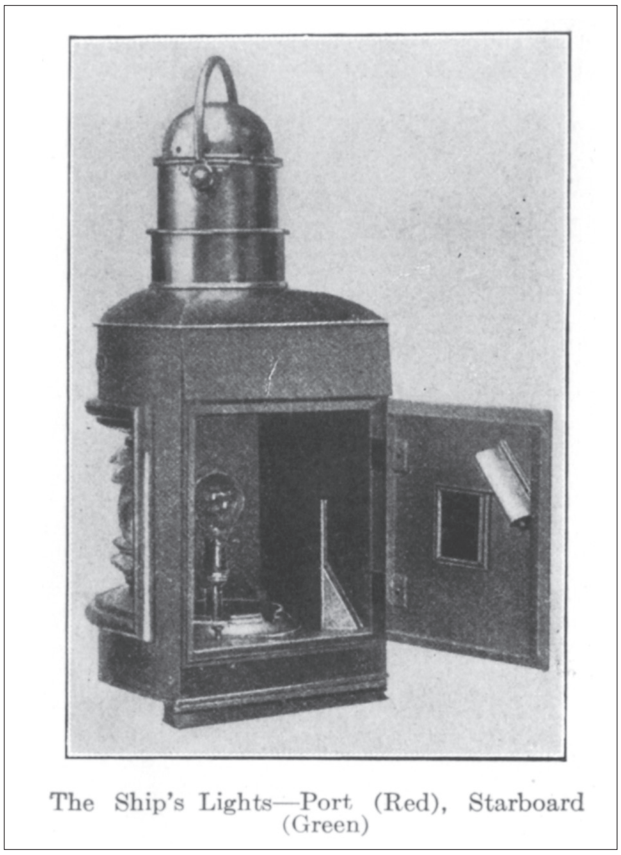


Fig. 22-61 **Starboard Sidelight on *Olympic*** – In this image, Captain Smith is looking out the starboard Bridge wing cab on *Olympic*. The starboard sidelight (indicated by the arrow) can be seen here as well as the access door behind it. The box in which the lamp is mounted is painted green, the color of the sidelight lens on this side of the ship. In later years the interiors of the sidelight boxes would be painted black.



The Ship's Lights—Port (Red), Starboard (Green)

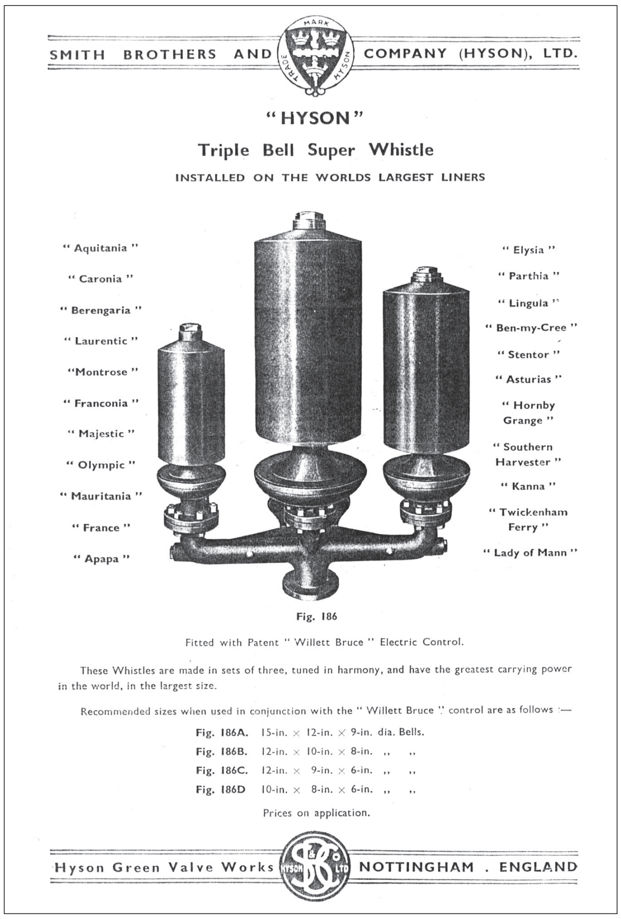
Fig. 22-62 **Sidelight** – An example of a common sidelight showing the interior. *(J. Kent Layton collection)*

Each of the two operational sets of steam whistles was manufactured by Smith Brothers & Co., of Hyson Green, Nottingham, and was supplied to Harland & Wolff, along with the electrical whistle control apparatus, by T. Downie & Co., Liverpool. These whistles were reported to be the largest made at the time, though their use was not exclusive to the *Olympic*-class liners, as some period sources would lead one to believe. (An identical set of whistles supplied to the *Mauretania* are still in existence and on display in a museum in Bodmin, Cornwall, at the time of this writing.) Each set consisted of three domes – or 'bells', as they were more commonly called – grouped together on a common branch piece. Proceeding from starboard to port, the three bells measured 9, 15, and 12in in diameter. The total height from the base of the branch piece to the top of the center dome was 4ft 2in, and the extreme width across the outer bells was 3ft 6in. The assembled weight of each whistle set was about 6¾cwt.

The whistles were blown with dry steam, with each set of whistles being supplied through a separate line led directly from the boilers, so as to ensure an immediate and clear response when activating the switch, without the deluge of water all over the lee side of the deck and the uncertain sputtering sound emitted while the condensed water was being blown out. This was accomplished with by use of a water separator supplied along with the Willett–Bruce whistle device,[23] which was fitted to the steam whistle feed pipe. The separator, which was fitted at a level just below the top of the casing, had a ball-loaded drain cock and was provided with a drain line to return any accumulated water to the boilers. In port, when the boilers beneath the whistles might be shut down, steam for the whistles could be taken from the auxiliary range. The objection to using this connection for sea service was the amount of water liable to collect in the system, but in port the signals were not of a vital nature.

The whistle controller boxes were mounted right above the top of the casing. This arrangement was in contrast to those of other manufacturers who offered controller boxes installed at a higher elevation, usually just below the whistle branches. With a low-mounted box, it was assured that freezing within the whistle pipe and valve could be avoided. The only drawback with this design is that the blast was not sharp – it took time to attain its full sound, and died down slowly.

The whistle arrangement consisted of (1) a pilot valve to enable the whistle valve to be opened without the application of a great deal of power; (2) a solenoid attached to the pilot valve; (3) a clockwork mechanism, to provide for the automatic energizing of the solenoid from the ship's electrical circuit; and (4) the provision of a number of control switches placed in various places on the Bridge. Thus, if the officer on watch desired to blow a single blast at any time, he could close one of the switches according to which part of the Bridge he might be on at the time.



SMITH BROTHERS AND COMPANY (HYSON), LTD.

"HYSON"

Triple Bell Super Whistle

INSTALLED ON THE WORLDS LARGEST LINERS

" Aquitania "
" Caronia "
" Berengaria "
" Laurentic "
"Montrose "
" Franconia "
" Majestic "
" Olympic "
" Mauritania "
" France "
" Apapa "

" Elysia "
" Parthia "
" Lingula "
" Ben-my-Cree "
" Stentor "
" Asturias "
" Hornby Grange "
" Southern Harvester "
" Kanna "
" Twickenham Ferry "
" Lady of Mann "

Fig. 186

Fitted with Patent " Willett Bruce " Electric Control.

These Whistles are made in sets of three, tuned in harmony, and have the greatest carrying power in the world, in the largest size.

Recommended sizes when used in conjunction with the " Willett Bruce " control are as follows :—

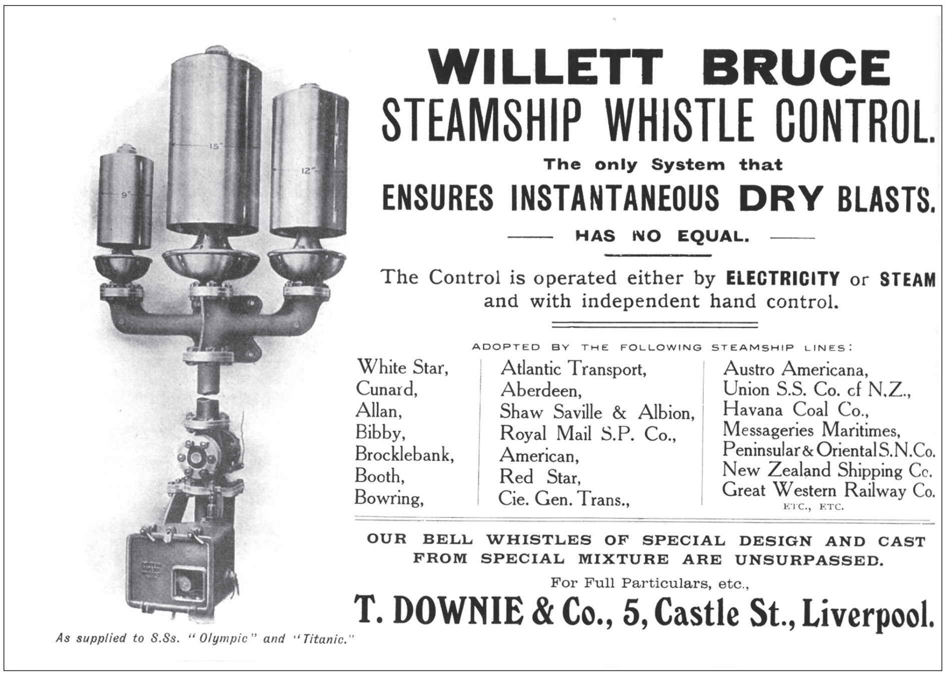
Fig. 186A. 15-in. × 12-in. × 9-in. dia. Bells.
Fig. 186B. 12-in. × 10-in. × 8-in. ,, ,,
Fig. 186C. 12-in. × 9-in. × 6-in. ,, ,,
Fig. 186D 10-in. × 8-in. × 6-in. ,, ,,

Prices on application.

Hyson Green Valve Works NOTTINGHAM . ENGLAND

Fig. 22-63 **Advertisement for Ships' Whistles** – In this page from a mid-1920s Smith Brothers catalog advertising triple bell whistle sets of the type fitted aboard the *Olympic*-class ships, the name '*Titanic*' is conspicuously absent for obvious reasons. (Scott Andrews collection)

If fog came and he was required to give the regulation fog signal of one blast of eight seconds duration every two minutes, he had only to turn the switch handle to a certain position whereupon the clockwork mechanism automatically closed the circuit at the required intervals and the whistle sounded as long as the switch remained in this position. The 'Rules of the Road' for steam vessels required the whistles to sound, at intervals of not more than two minutes, a prolonged blast while in fog. However, well-regulated vessels would sound their whistles at intervals of about one minute, with blasts of about four to six seconds, as obviously large steam-powered vessels under power could cover a fair distance in two minutes. The Willett–Bruce device was fitted with the clockwork contacts arranged to allow it to blow the whistles at intervals of one minute. Usually the blowing of whistles in fog at one-minute intervals did not happen for long periods of time, as this was usually



WILLETT BRUCE
STEAMSHIP WHISTLE CONTROL.
The only System that
ENSURES INSTANTANEOUS DRY BLASTS.
HAS NO EQUAL.

The Control is operated either by ELECTRICITY or STEAM and with independent hand control.

ADOPTED BY THE FOLLOWING STEAMSHIP LINES:

White Star,
Cunard,
Allan,
Bibby,
Brocklebank,
Booth,
Bowring,

Atlantic Transport,
Aberdeen,
Shaw Saville & Albion,
Royal Mail S.P. Co.,
American,
Red Star,
Cie. Gen. Trans.,

Austro Americana,
Union S.S. Co. of N.Z.,
Havana Coal Co.,
Messageries Maritimes,
Peninsular & Oriental S.N.Co.
New Zealand Shipping Co.
Great Western Railway Co.
ETC., ETC.

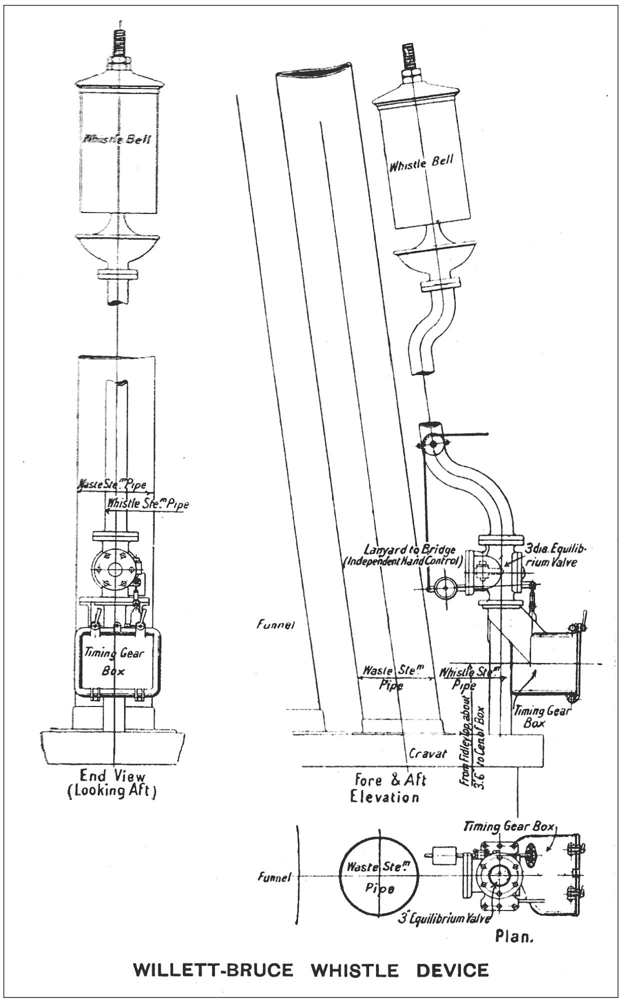
OUR BELL WHISTLES OF SPECIAL DESIGN AND CAST FROM SPECIAL MIXTURE ARE UNSURPASSED.

For Full Particulars, etc.,

T. DOWNIE & Co., 5, Castle St., Liverpool.

As supplied to S.Ss. "Olympic" and "Titanic."

Fig. 22-64 **Willett-Bruce Advertisement** – Original advertisement for the Willett-Bruce whistle control device used on *Olympic* and *Titanic*. *(*The Shipbuilder*/Authors' collection)*



Whistle Bell
Waste Ste^m Pipe
Whistle Ste^m Pipe
Timing Gear Box
End View (Looking Aft)
Whistle Bell
Lanyard to Bridge (Independent Hand Control)
3 dia. Equilibrium Valve
Funnel
Waste Ste^m Pipe
Whistle Ste^m Pipe
Timing Gear Box
From Fiddley top about 3'6" to Centl Box
Cravat
Fore & Aft Elevation
Timing Gear Box
Funnel
Waste Ste^m Pipe
3" Equilibrium Valve
Plan.
WILLETT-BRUCE WHISTLE DEVICE

Fig. 22-65 **Willett-Bruce Whistle Control Device** – A drawing from a period engineering journal showing the principal parts of the Willett-Bruce whistle control device. *(*The Engineer*/Authors' collection)*

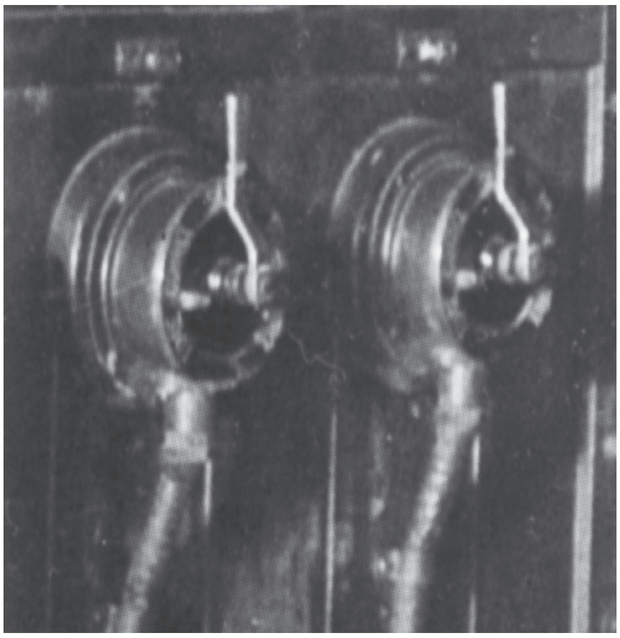


Fig. 22-66 **Whistle Control Switches** – This image from another White Star Line ship shows two whistle control switches similar in design to those used on *Titanic*.

done while locating another ship, and hand activation was then preferable. *Titanic* also had a Norwegian fog horn and a gong for use while at anchor.[24]

As mentioned in some of Downie & Co.'s advertisements, steam whistle soundings were also used for emergency situations, including Morse signaling. White Star Line regulations also required the whistle to be sounded at noon daily, unless the vessel was in port.

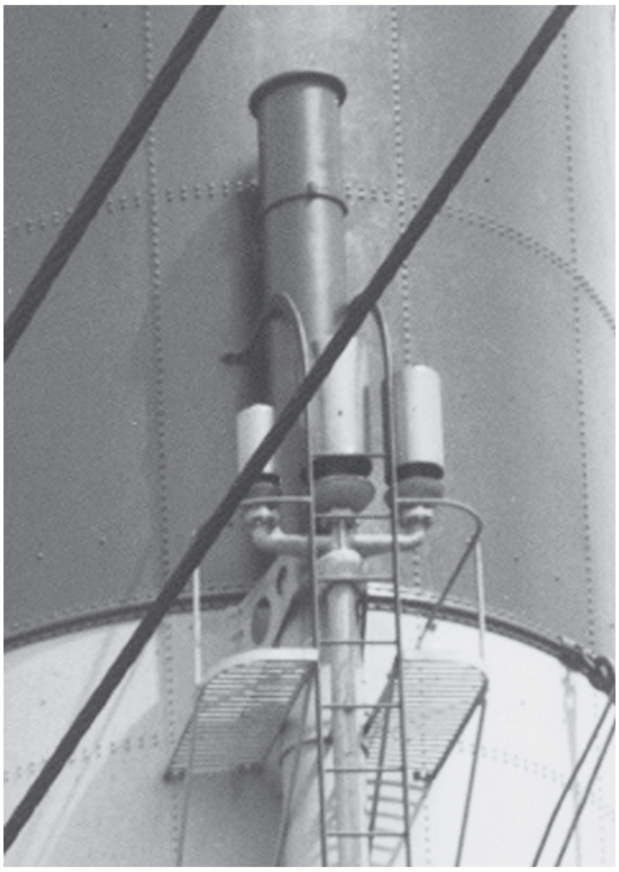


Fig. 22-67 **Whistles on *Olympic*** – One of the operational whistle sets on *Olympic*.

FLAGS

Titanic carried a full complement of flags as required for company identification, signaling, dressing ship and displaying the colors of Great Britain and the countries at which the ship would call. This included White Star house flags at 3 yards length, Blue Ensigns at 3, 5 and 7 yards, American and French ensigns at 3 yards, Pilot Jacks at 2½ yards, US Mail flags, and Royal Mail pennants. If *Titanic*'s flag complement was consistent with specifications for the *Olympic*-class ships in 1914, she would have also carried two Red Ensigns at 3 yards, American ensigns at 2 yards, plus French ensigns of the corresponding smaller size.

For signaling, *Titanic* carried International Code flags (8ft 0in x 5ft 6in for the rectangular flags), four International Code flags for the ship's name, and one set of flaglines with flags for dressing ship, these being in addition to the International Code flags listed above. If the 1914 flag specifications can be relied on here as well, *Titanic* would have also carried two Blue Peters at 7ft and one Blue Peter at 4ft in addition to the flags of the same type in the International Code flag sets; and one or more Pilot flags. There were also smaller flags, square in shape, that were flown from the portable flagpoles on the docking bridge. These consisted of red flags and white flags and are believed to have been used for signaling tugs. (Note: in nautical terminology, ships are said to 'wear' flags. For clarity to the reader, however, the term 'fly' is used here.)

House flag

Titanic was rigged with two sets of halyards at each mast, each of which ran through sheaves in the truck of the teak pole at the top of the mast. The White Star Line house flag was always flown at the main (mainmast), as was customary with merchant ships. A house flag, along with the funnel colors, identified a ship as belonging to a particular shipping line. The practice of flying a unique owner's flag dates to the late 1700s, but the practice originated as a means of signaling the ship's arrival to its owners rather than to identify the shipping line to others. By the mid-1800s, though, there were very few shipping lines that could not be readily identified by their own unique flags, and in 1882 the first edition of Lloyd's *Book of House Flags* was published. Although house flags were originally flown only during a ship's arrival in port, by 1815 it had become normal practice to fly the house flag continuously during daylight hours for the entire time a vessel was in port, entering port, or leaving port.

The flag of the White Star Line was a swallowtail, consisting of a large 5-point white star on a red field.[25] It first appeared in 1854 on a sailing notice for the clipper ship Red Jacket, chartered for the Liverpool–Melbourne (Australia) route. At this time the name 'White Star Line' was not a business name, but rather the name by which the line was popularly known.

Photographs of *Titanic* and *Olympic* show the standard White Star Line house flag to be 3 yards in length, with a proportion of 1:2. Later (1914) specifications for the *Olympic*-class ships list two types of house flags, medium and storm (three of each), the difference relating to weight. The storm flag was of heavier fabric and shorter length to better resist strong winds.[26] As the White Star house flag was flown daily in port regardless of weather, *Titanic* had to carry a sufficient number of flags not only for varying conditions, but to allow for rotation to prevent premature wear. The house flags, like the ensigns, were made of English long-fibered wool bunting, this being superior to any other fabric available at the time for strength and durability at sea.

Titanic's Captain Smith is often believed to have had the right to fly the White Star Line Commodore flag, which was a variant of the house flag with a white border. This is incorrect, however; the title of Commodore of the White Star Line fleet was discontinued in 1882

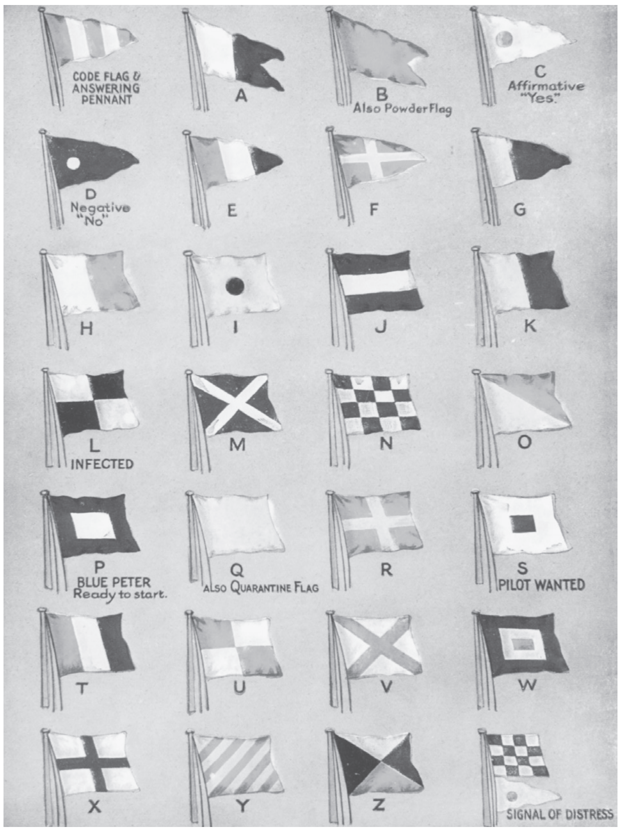


Fig. 22-68 **International Code Flags.**

after being held by Commodore Hamilton Perry of the *Britannic*. The title was not reinstated until 1922, when it was conferred upon Captain Sir Bertram Fox Hayes, formerly of *Olympic*, when he took command of the *Majestic*. (Smith held the rank of Commander in the Royal Naval Reserve, which may account for the misinformation.)

National ensigns

It is often thought that the flag flown at the foremast was a 'destination flag'. While the flag at this location did at times reflect the ship's destination – the US flag flown at Southampton, for example – the flying of a 'courtesy flag', or 'courtesy ensign' at this location always took precedence when protocol dictated its use.

An ensign is the national flag of a country flown at sea. It may be the same design as the flag flown on land – as with the US 'Stars and Stripes'[27]– or it may be a variant thereof, as with the French and British ensigns.[28] A 'courtesy ensign' is the civil (non-military) ensign of a country, flown by a foreign vessel to honor that country when in that country's waters. While flying another country's ensign was originally done to show the vessel's destination, over time this practice evolved to be primarily a means of paying respect to a foreign country at which the ship was calling. There were no official Admiralty or international protocols regarding the courtesy ensign, but general custom and practice held for it to be hoisted upon arrival at a foreign port, for the duration of the vessel's time in port, and departing port.

The flags flown by *Titanic* at the foremast throughout her maiden voyage were consistent with the above protocols and with White Star Line practice as demonstrated by *Olympic* over the years during her non-wartime service. *Titanic* flew the US ensign at the foremast on April 10 prior to departure, reflecting her final destination of New York, and continued to fly this ensign as the ship proceeded down Southampton Water. The French ensign was flown entering Cherbourg as courtesy demanded, and until sunset, which occurred shortly after *Titanic* dropped anchor. The next morning, the US ensign was flown into Queenstown and

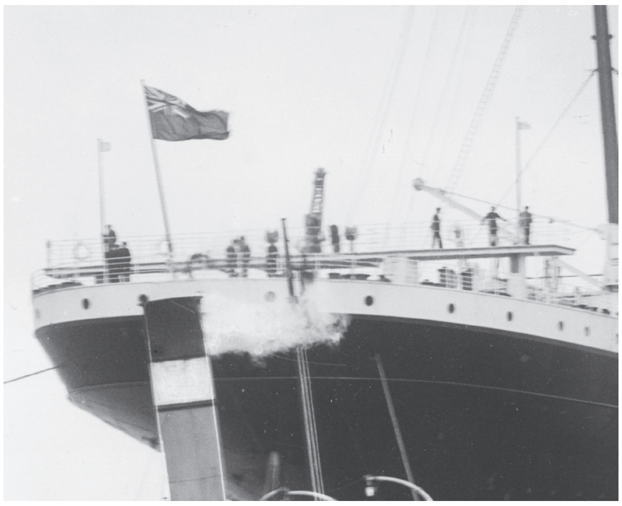


Fig. 22-69 **Docking Bridge Flags** – In this image taken of *Titanic* on her sea trials, two flags can be seen flying from the portable teak poles on her Docking Bridge.

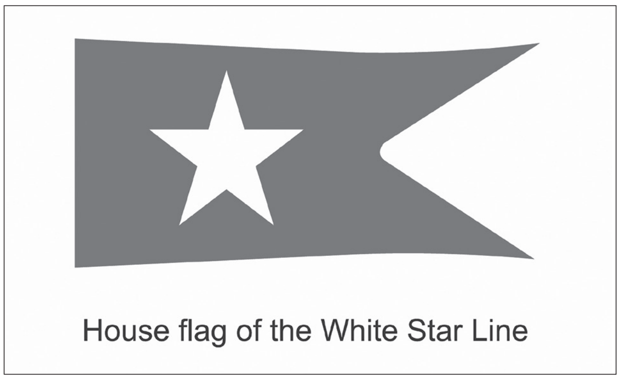

House flag of the White Star Line

Fig. 22-70 **White Star Line House Flag** – The flag shown here, drawn based on careful examination of numerous photographs, shows the shape and proportions of the White Star Line house flag as flown on *Olympic* and *Titanic*. These flags were not manufactured with the swallowtails flaring outward; the flare resulted primarily from the stretching of the fabric from flying in the wind. *(Illustration by Art Braunschweiger)*

remained flying for the duration of the ship's time in port. This may seem contrary to protocol, but Ireland was not a sovereign country in 1912 and the flying of a courtesy ensign did not apply to 'home waters'. The flying of the US ensign at Queenstown was instead a display of the ship's final destination, in accordance with an Admiralty directive of 1890 regarding the flying of the US ensign by British mail steamers at Queenstown. Had *Titanic* reached New York, she would have again flown the US ensign for her arrival, thereby satisfying the demands of courtesy for entry into her destination port.

Titanic was also required to fly the British ensign to display her nationality. Merchant ships customarily flew their national ensigns at the stern, in accordance with practice dating as far back as the 1630s. On *Titanic*, there was an ensign staff 24ft in length that extended back over the railing at an upward angle of approximately 66° from the horizontal. It was made of rolled steel, tapered at the bottom to form a single metal bar shaft fastened to the deck with a lug, which allowed it to be swung forward over the deck for maintenance as necessary.

There were two variations of the British ensign for merchant service, the Red Ensign[29] and the Blue Ensign. (A third, the White Ensign, was used only in naval service.) The Red and Blue Ensigns consisted of a flag with a field of solid color (red or blue, depending on the ensign) with the red, white and blue Union flag (Union Jack) as the canton.

Use of the various ensigns was regulated by the Admiralty under the Queen's Regulations and Admiralty Instructions and also the Merchant Shipping Act of 1894, which stated that: 'The Red Ensign usually worn by the merchant ships, without any [modification], is hereby declared to be the proper national colors for all ships or boats belonging to any British Subject'. However, if a ship was commanded by an officer of the Royal Naval Reserve, and had at least ten R.N.R. officers and/or crew aboard, an Admiralty warrant could be issued to permit the flying of the Blue Ensign. This warrant remained valid upon the captain's transfer to another ship within the same shipping line, but if the captain took command of a ship in another line he was required to re-apply for a warrant. Captain Smith held such a warrant – number 690 – and this had to be noted on the ship's Articles of Agreement. (It should also be noted that members of the Royal Naval Reserve were not necessarily former naval personnel – they were merchant marine personnel who joined the Naval Reserve and received a limited amount of training.) When the Blue Ensign was originally authorized for use in 1862, it was adorned ('defaced') with a crown and the letters 'RNR', but these were omitted from 1864 onward.

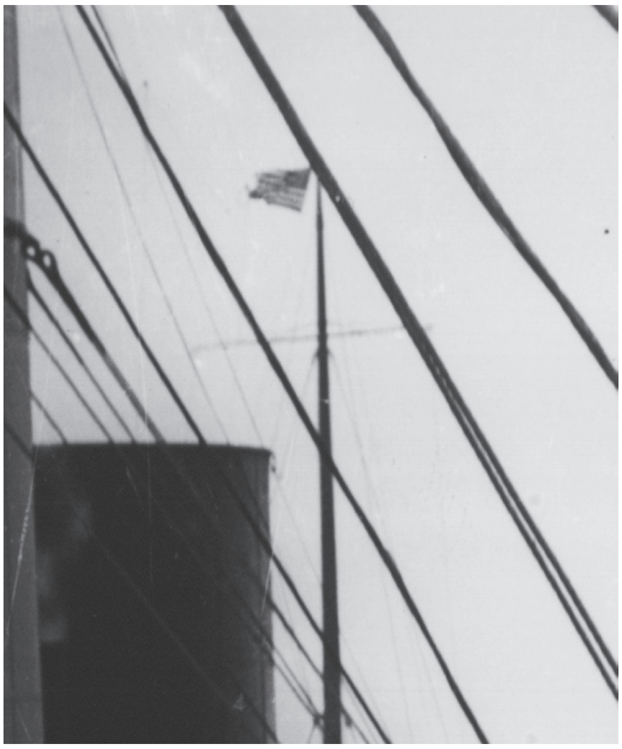


Fig. 22-71 **US Ensign Flying on *Titanic* at Queenstown** – *Titanic* flying the US ensign at Queenstown.

Of the various sizes of Blue Ensigns carried, the largest (5 yards in length) was flown at the stern. Later specifications (1914) would also list an even larger ensign, 7 yards in length, which does appear very occasionally in later photographs of *Olympic*. An ensign this size was customarily known as a 'Sunday ensign', normally flown only on special occasions. Neither *Titanic* nor *Olympic* flew an ensign of this size on their maiden voyages, so it can be safely assumed that this size was not carried by *Titanic*.

The flying of flags at sea merits some discussion here. Most artists' illustrations of *Titanic* show her at sea with all flags flying. However, photographs show that *Olympic* normally hauled down the flags from both masts just prior to reaching the open waters of the English Channel.[30] This is consistent with photographs of other liners, which routinely show no flags flying at sea. A distance of fifty nautical miles from land is often given as a determinant of whether or not flags would be flown, but this is not born out by photographic evidence – there are many photographs of ships in coastal waters with no flags at the mastheads, even with land clearly visible. As to the ensign at the stern – normally the Blue Ensign – it is likely that this continued to be flown for the duration of the Atlantic crossing. Flag specifications list no less than four large-size ensigns for use at the stern, and the fact that this many were carried makes it likely that an ensign was intended to be flown daily at this location.

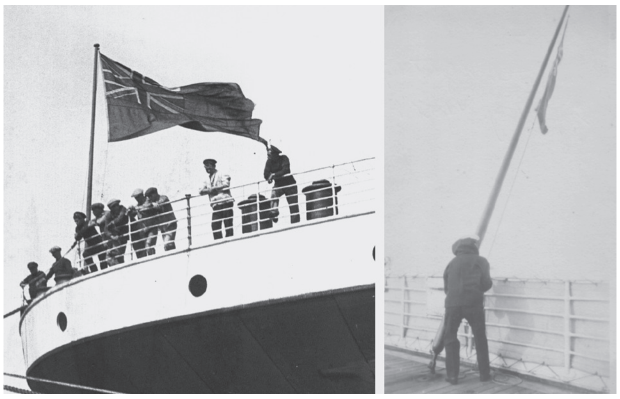


Fig. 22-72 ***Olympic* flying the Blue Ensign** – At left, the Blue Ensign flying from *Olympic*'s stern. At right, an image showing the ensign staff. *(Left image authors' collection; right image Peter Davies-Garner collection)*

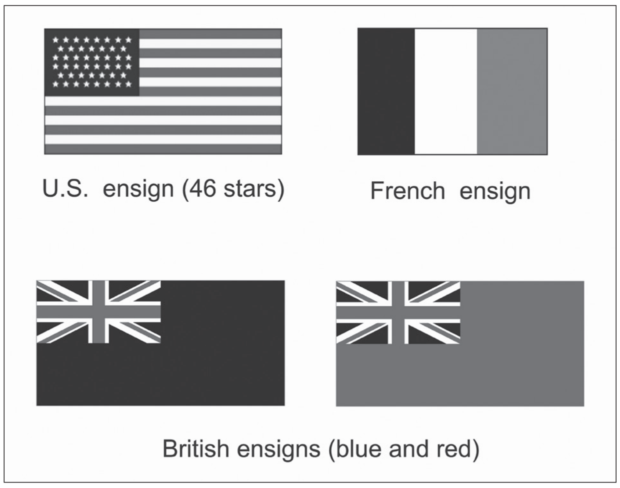


Fig. 22-74 **U. S., French and British National Ensigns**. *(Illustration by Art Braunschweiger)*

Pilot Jack

In port, or when the ship was dressed with flaglines, another flagpole was seen at the bow. This was the jackstaff, so named for the flag flown here, which is always termed a jack. This jackstaff, 16ft in length and made of teak, was fitted at the forepeak just aft of the stem head casting. Special attention must be given to the flag flown here, seen while *Titanic* was dressed in Southampton. This was the British Union flag with a white border added, the border being one-third the breadth (vertical measurement) of the Union flag in the center in accordance with regulations set forth in 1833. Modified as such, it was used to dress the bow of a ship in merchant service, and was known as the Pilot Jack.

As its name suggests, as of 1894 it was also legal in British waters for use as a pilot summoning signal (indicating that the ship needed the services of a pilot), but only when flown from the foremast or signal halyard. However, in 1900 the International Code of Signals committee recommended that its use as a pilot flag be discontinued in favor of the internationally recognized Code flag 'S', which carried the same meaning. For the *Olympic*-class ships, it was used strictly for ceremonial purposes when dressing ship. The traditional name 'Pilot Jack' remained, though, not to be confused with the term 'Pilot Flag' which meant the presence of a pilot aboard.[31]

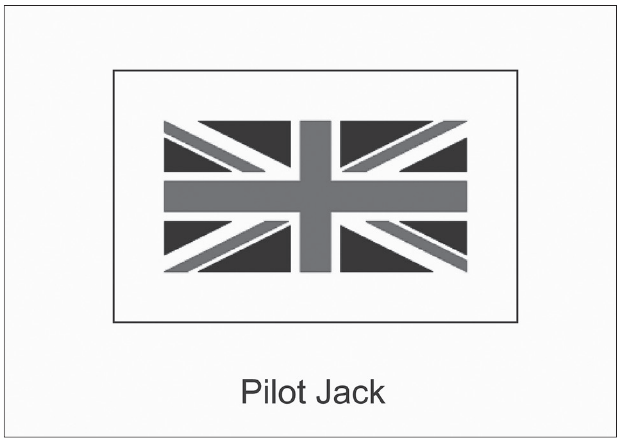


Fig. 22-73 **Pilot Jack**. *(Illustration by Art Braunschweiger)*

As a matter of interest, it should be noted that there was one additional and somewhat unusual use for the Pilot Jack: it could be used to signal British naval vessels to report the sighting of enemy vessels of war. If used for this purpose, it would be hoisted from the main signal halyards in a group with three International Code flags, the specific combination of which allowed a merchant ship to communicate in one hoist the nationality, number, type and approximate course of enemy vessels sighted.

Dressing ship

While in the White Star Line dock, *Titanic* was dressed out in her compliment of flags to commemorate the occasion of her presence in Southampton for the first time. The most noticeable feature of a dressed ship was the line of signal flags up and over the ship, along a fore-and-aft line from bow to stern. The etiquette for dressing ship in this fashion was described in the book *Brown's Signalling* in part as follows:

> *On ceremonial occasions, it is sometimes required to dress ship. This is carried out by hoisting masthead flags 'rainbow fashion'. In the latter case, on board a two-masted vessel, the line should run from stem to foremast head, thence to mainmast head and down to taffrail.*

Contrary to what is sometimes believed, *Titanic*'s flaglines did not spell out 'SUCCESS' or any other message; the flags were simply arranged at random. *Brown's Signalling* recommended that:

> *Particular attention is to be devoted to the arrangement of flags so that when flying they will have a symmetrical appearance. The flags should be evenly spaced and the same number of square flags between pendants. Since there are only two burgees in the International Code the best position for them is at each end of the line. The appearance of a string of flags is often completely spoilt by the line sagging in the middle. It is hard to avoid such an occurrence when flags are merely toggled together, but may be successfully overcome by fitting dressing lines. These lines may be made of light wire or small manila. The flags are seized to the lines, the middle of the hoist being secured to the line with a whipping of sailmaker's twine. When seizing the flags to the line, the utmost care is to be taken to ensure the flags are evenly spaced; holidays between flags spoil the effect. If manila rope is used, be sure the rope is thoroughly stretched before setting up otherwise sagging is sure to occur.*
>
> *The order of the flags may be left to the discretion of the responsible officer. The ensign is carried in its proper place. No ensigns of any kind are to be used in dressing lines.*

Titanic's flaglines were made of 1½in wire rope, with the flags fixed to the lines so as not to require rigging them on each occasion of use. This also eliminated the need to arrange the flags for proper symmetrical appearance each time and reduced the time required to dress ship.

When hoisted aloft, *Titanic*'s flag line ran from the stem head casting at the bow to the foremast just below the Marconi array, over the funnels to the corresponding point on the mainmast, and then down to the after end of the Poop Deck. The foremost section of the line was the 'fore-down' line, the section between the masts the 'fore-to-main' line, and the aftermost section the 'main-down' line. The fore-to-main line was stayed to the Boat Deck to prevent the wind from whipping the line up and over the Marconi array, two stays being fixed along its length. One stay ran down between the Nos 1 and 2 Funnels, and the second stay between the Nos 3 and 4 Funnels.

Brown's Signalling further specified that:

> *The flag to fly at the masthead depends upon the nature of the occasion for dressing ship. For instance, on the King's birthday fly the national ensign. When abroad and the same circumstances prevail, fly at the main the ensign of the country visited, wearing, of course, the British ensign aft.*
>
> *A vessel should not be dressed 'rainbow fashion' when under way, but, instead, fly masthead ensign only. Should you find on entering port all vessels at anchor dressed, endeavor to have your dressing lines all ready to hoist as soon as the anchor is let go.*

When *Titanic* was dressed at Southampton, she flew the White Star Line house flag from her mainmast, and the Blue Ensign – in essence, her national flag at sea – from the foremast. The Pilot Jack, as previously noted, flew from the jackstaff at the bow. Had she arrived in New York, it is certain that once berthed she would have dressed ship as soon as time permitted, just as *Olympic* did on her maiden arrival one year earlier.

Signal flags

As noted, *Titanic* carried two sets of signal flags exclusive of those used to dress ship. Sending messages by means of hoisting flag signals was a common way of communicating from ship to ship, or between the ship and shore. The signal flags were flown in those positions where they could best be seen, and where they would be unobstructed by smoke or structures. Although regulations permitted the use of signal flags in various locations on a ship, practicality demanded that the halyards used most often for signaling be readily accessible to the bridge. For this purpose, *Titanic* was rigged with two sets of signal halyards located on the Bridge wings, one set each to port and starboard.[32] The halyards ran to iron blocks attached to a 1½in galvanized steel wire rope high above the Bridge, spanning from the top of the forward funnel to the foremast just above the iron ladder. This was called the signal stay. The signal halyards were made of special soft laid rope with some of the yarns reverse spun so that the rope was very flexible and not liable to stretch or kink.

The signal flags carried by *Titanic* had their origins in *The Commercial Code of Signals for the Use of All Nations*, published in 1857. This was the first system using alphabetical letters extensively, although the signaling alphabet only included 18 letters. This evolved over time to *The New International Code of Signals*, revised in 1901 to include all letters of the alphabet. There were no flags for numbers, however, these being made by codes consisting of letter combinations; numeral flags would not appear in the International Code until 1937.[33] A set of International Code flags consisted of twenty-seven flags, one for each letter of the alphabet and one distinct Code and Answering pennant. This pennant, with vertical bands of red/white/red/white/red, served two purposes: it was hoisted by the receiving ship to acknowledge that each hoist of flags by the sending ship was seen and understood, and was also flown above or below groups of Code flags when making various signals.

The procedures and protocols for flag signaling is a subject all of its own, but a brief explanation will suffice here. Signals were made by hoisting flags in groups of up to four letters, the receiving ship acknowledging each hoist of flags before the sending ship hoisted the next group. While messages could be spelled out by individual letters, the International Code conveniently permitted a means of sending messages using certain flags flown singly, in groups of two flags, or by flying one, two, three or four flags below the Code pennant. Urgent signals relating to the vessel's speed, direction, engines, and other matters were signaled by the Code pennant over one flag. Other predetermined messages were signaled by flying two flags without the Code pennant. In this last system alone, the International Code provided for 674 messages in sixty-four categories, ranging from the routine ('SH' – 'where are you bound?') to the urgent ('OR' – 'fire in hold amongst the cargo').

Three- and four-flag groups (the Code pennant plus two or three flags) were used to signal messages relating to latitude and longitude, time, bearings, and other categories, including general vocabulary. The General Vocabulary section of the code by itself was very extensive, and consisted of flag signals for over 15,000 individual words (Code pennant plus flags CXA through ZNP). As *Brown's Signalling* explained:

> General Vocabulary – This is the index to most of the Signalling required in general practice, and to which chief reference is made when making a Signal. It embraces Urgent and Important Signals, also Auxiliary Phrases. This part, as in all the others, being in alphabetical order, you have first to determine the subject of your Signal – such as 'Cargo', 'Leak' 'Wreck', 'Enemy', 'War' &c., and open the Signal Book at that word, and all possible renderings of it are conveniently arranged from which to select the Signal that suits the occasion.

While a Quartermaster would remember the most significant and frequently used signals, a codebook was obviously required for immediate reference and this would be kept on-hand as well. As Code books were printed internationally in different languages, this readily allowed for communication between vessels even if no common language was spoken between the crews.

Titanic also carried four additional International Code flags for display of the ship's Distinguishing Signal. This 4-letter group – 'HVMP' for *Titanic* – was permanently assigned to her and served to identify the ship when exchanging signals with another ship or a shore station. The use of four-letter signals for ship

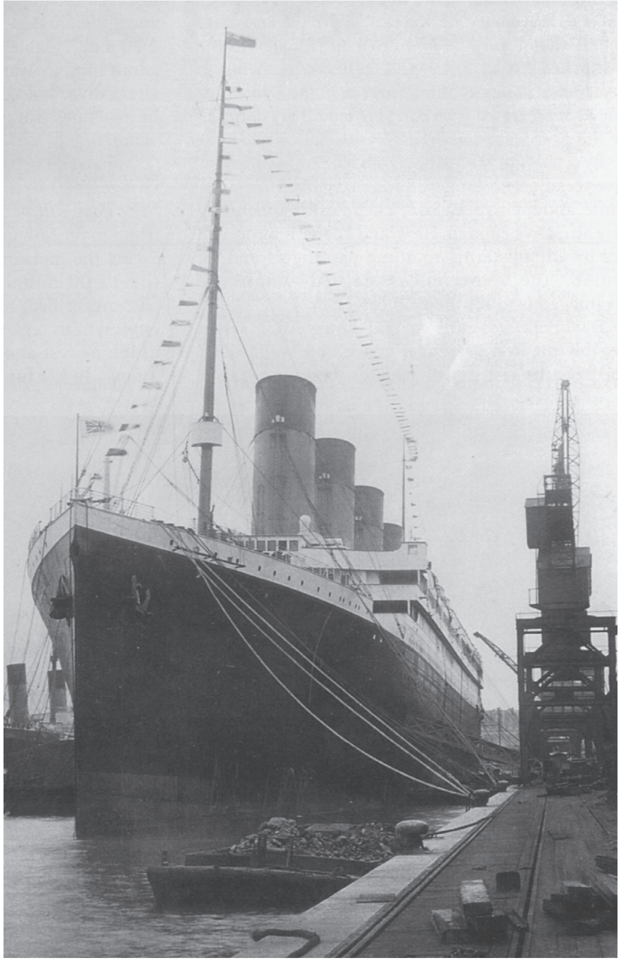


Fig. 22-75 ***Titanic* Dressed With Flaglines** – This image of *Titanic* dressed out on Thursday April 4, 1912, shows the Pilot Jack flying at the jackstaff and the Blue Ensign flying at the foremast. Coal barges are alongside and painters are working from scaffolding rigged from the coaling outriggers to give her paint a final touch-up before the maiden voyage.

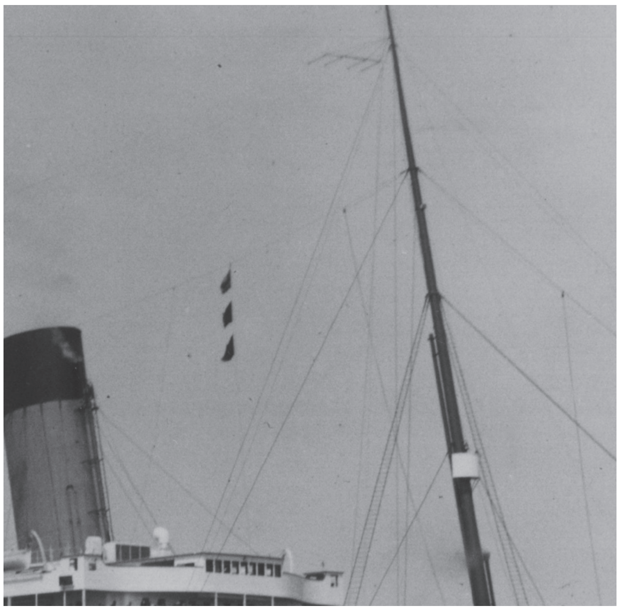


Fig. 22-76 **Signal Halyards** – Signal flags hoisted on *Olympic*.

identification eliminated the need to spell out lengthy ship names, and carrying four separate Code flags of the required letters assured that *Titanic* could always 'make her number' in addition to any other signals hoisted. In addition, it was frequently the practice for ships to keep the flags of their Distinguishing Signal permanently bent (tied) to each other to permit rapid use when required. Merchant ships' Distinguishing Signals[34] were published in the British Code List, a copy of which would always be kept with the Code Book. (Naval ships, or 'men-of-war', were identified in a separate list.) Distinguishing signals were also included in an international list of wireless stations published under International Telegraph Regulations, this list being divided into coast stations and ship stations. It should be noted that a ship's four-letter Distinguishing Signal was not the same as the three-letter wireless call sign, and the wireless call sign – in *Titanic*'s case, 'MGY' – is what was used to identify the sending ship when transmitting a wireless message via Morse code.

To initiate an exchange of signals with another vessel or a shore station, the sending ship would hoist her Blue or Red Ensign with the Code flag beneath it, and if other vessels were nearby, the distinguishing signal of the vessel or station with which she desired to communicate. The book *British Flags*, published in 1920, describes the procedure by which the exchange of signals followed:

> On seeing this signal the ship (or station) hoists the 'Answering Pendant' (i.e., the Code flag) at the 'Dip', that is, some little distance below its position when hoisted 'close up' to the block (through which) the signal halliards are rove. The first ship then hoists her own distinguishing signal, consisting of the four letters appropriated to her name, and then proceeds with the signal she wishes to make. When the first hoist is noted down and translated in the ship receiving the signal, this ship hauls the answering pendant 'close up' to show that the signal is understood and keeps it there until the signaling ship has hauled that hoist down; the answering pendant is then again lowered to the 'Dip' until the next hoist is disposed of, and when the ship signaling has finished, she hauls down her ensign to indicate the message is at an end.

Blue Peter

Certain flag signals carried a special message when flown by themselves, without the Code pennant or any other flags. This included the International Code flags 'C' and 'D' for 'yes' and 'no' respectively, and several others. One of which, perhaps better known than any other, merits discussion here.

The International Code flag 'P', a square or rectangular blue flag with a white center of the same shape, was known as the 'Blue Peter', and was flown prior to sailing to signal that the time of the ship's departure was approaching. This flag dates as far back as 1777, when it was used by the British Navy for this purpose. The name 'Blue Peter' is recorded as early as 1801, and many theories have been proposed for its origin, but none have ever been proved and 'Blue Peter' may have been nothing more than an unofficial name for this flag in the nautical vernacular. *Titanic*'s officers had the option of hoisting the Blue Peter from one of the foremast halyards or from the halyards on the Bridge. They also had the option of hoisting a second Blue Peter from one of the halyards on the mainmast, as was done on occasion with *Olympic*. Flying the Blue Peter was not mere symbolism, but a useful and necessary signal to ensure that persons ashore and other ships knew of the ship's imminent departure in an era when public address systems were unknown and personal timepieces were not as affordable or widely carried as today. As previously noted, *Titanic* most likely carried three Blue Peters in addition to the flags of the same type within the sets of International Code flags.

Mail pennants and flags

Special note must also be made of the Royal Mail pennant flown by *Titanic*. As noted in *Flags of All Nations*, published in 1899, this was instituted in 1884 as a 'pendant for Vessels employed in carrying Her Majesty's Mails'. As a Royal Mail steamer under the White Star Line's contract with the British government, *Titanic* loaded mail at Southampton for Cherbourg, Queenstown and New York, also picking up eastbound mail at Cherbourg and Queenstown. The Royal Mail pennant, of elongated triangular shape, was emblazoned with the words 'Royal Mail', below which were the symbols of the British postal service (the post horn and Tudor crown), all of which were in red. This pennant was flown from one of the mainmast halyards at some distance down from the masthead where it would be clear of the house flag, the stays and the other set of halyards. (In later years, on *Olympic*, this pennant would be shifted to the halyards at the foremast.)

Titanic flew the Royal Mail pennant leaving Southampton, entering Cherbourg, and entering Queenstown. It also would have been flown on the arrival to New York, not because it would confer priority in docking, but to announce the presence of mail on board that would need to be taken off. The handling of mail is detailed in the chapter on cargo handling.

Had *Titanic* reached New York, she would have also carried mail on the return trip. In 1905 International Mercantile Marine, which owned the White Star Line, was awarded a ten-year contract by the US government to carry the mails from New York to Southampton, calling at Plymouth and Cherbourg en route. In doing so, *Titanic* would have flown the US Mail flag at the same position as the Royal Mail pennant occupied westbound. This flag, rectangular in shape, consisted of the letters 'USM' on a white field. As on the westbound trip, all the mail carried would have to be sorted prior to reaching the ship's next destination.

Pilot flag

Titanic would also have carried a British Pilot flag. This flag, valid only in British waters, was a rectangular flag of white over red, established by the Pilotage Act of 1808 and later codified in section 612 of the Merchant Shipping Act of 1894. Regulations specified that it be flown whenever a licensed pilot was aboard.[35] A pilot would be aboard a ship departing and arriving at a port, and once on the bridge assumes responsibility for the navigation of the ship. In Britain, pilotage was (and still is) compulsory in certain waters – *Titanic*'s route from Southampton docks to the English Channel, for example – and qualified individuals were licensed by the Corporation of Trinity House. Ships inbound to a port would typically be met by a pilot boat at designated locations (boarding grounds) outside the approach to harbors or ports, at which point the Pilot would transfer to the inbound ship. Approaching Queenstown, for example, *Titanic* was met off Roche's Point by Pilot John Whelan, having been rowed to the ship by a four-man pilot boat.

The use of the Pilot flag was outlined in section 613 of the Merchant Shipping Act, but this requirement was not strictly followed where the vessel was well known and the pilot arrangements were known in advance. This may be the reason why it was not flown by *Titanic* on the one occasion of her departure from Southampton, even though there was a qualified pilot aboard.[36] The Pilot flag would have been included in *Titanic*'s flag complement, though, as *Olympic* did fly it out of Southampton on some occasions during her career.[37] The Pilot flag is of the same general design as the square flags of the International Code, but its color and pattern was unique and could not be mistaken for any other signal flag: there was no other flag that was horizontally divided into two colors.

The Pilot flag should not be confused with the flag used to request a pilot. The 'pilot wanted' flag was the International Code flag 'S', which has the reverse appearance of the Blue Peter: a rectangular white flag with a blue square in the center. As previously noted, this flag was recommended and adopted in 1901 by the International Code of Signals Committee as the official pilot-summoning signal for merchant ships when flown by itself or under the Code pennant, the intent being to discourage the use of the white-bordered Union Jack as a signal for the same purpose. However, *Titanic* would

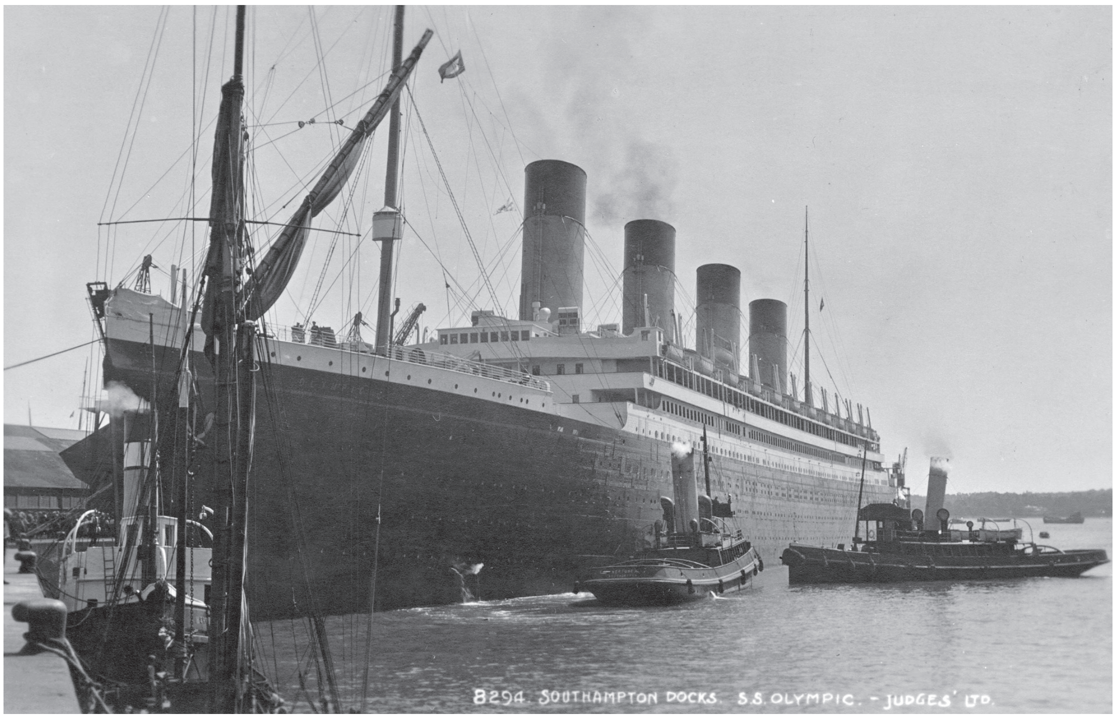


Fig. 22-77 ***Olympic* with Blue Peter** – In this image of *Olympic* at Southampton taken later in her career, she is flying the Blue Peter prior to departure. The Royal Mail flag can be seen behind it on another halyard. *(Daniel Klistorner collection)*

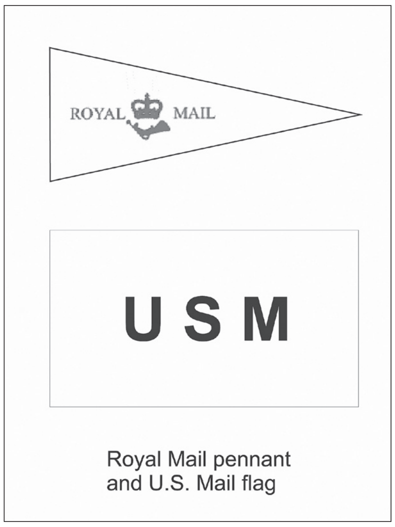


Fig. 22-78 **Mail Flags**. *(Illustration by Art Braunschweiger)*

not normally need to signal for a pilot. Her arrival and departure times would have been known well in advance, and anticipated by the pilot service as well as the individual pilots who customarily provided pilotage for the White Star line.

MORSE SIGNAL LAMPS

Titanic and *Olympic* were fitted with Morse lamps: electric flashing lights fitted on the roofs of the wing cabs on each side of the Navigating Bridge, designed to meet Board of Trade requirements for signaling to other ships at night by means of the Morse code. These were a new design of Morse lamp of Wightman's patent, supplied by McGeoch & Co. Ltd of Birmingham. The control switches were located on the forward bulkhead inside the wing cab enclosures. The height of the lamps (over 65ft above the water), the special lenses with which they were fitted, and the fact that the Bridge area was always darkened at night, ensured that the Morse lamps could be seen at a great distance.

Each lamp consisted of a cylindrical glass lens clamped between two brass plates, secured together with three brass rods. A dome top was attached to the upper plate and extended 3in beyond the lens. This lamp assembly was fitted to a pole that raised it above the wing cab roof. Inside the lens was an electric light bulb of 25 to 50 candlepower. Such a light source could never have been seen at any distance except for the special character of the lens: a circular dioptric lens, similar in appearance and identical in function to the Fresnel lens of a lighthouse. Each glass lens was cast with concentric rings of glass prisms which concentrated and focused the light from the small electric bulb into a much brighter and more powerful beam that radiated straight out over 360° in a horizontal plane.

Signaling with the Morse lamps was done from inside the Bridge wing cabs. The manufacturer described the operation as follows:

> Main terminals are fitted in the lantern for attaching a twin flexible cable, about 50ft long, leading down to a watertight Morse key on the bridge, which is

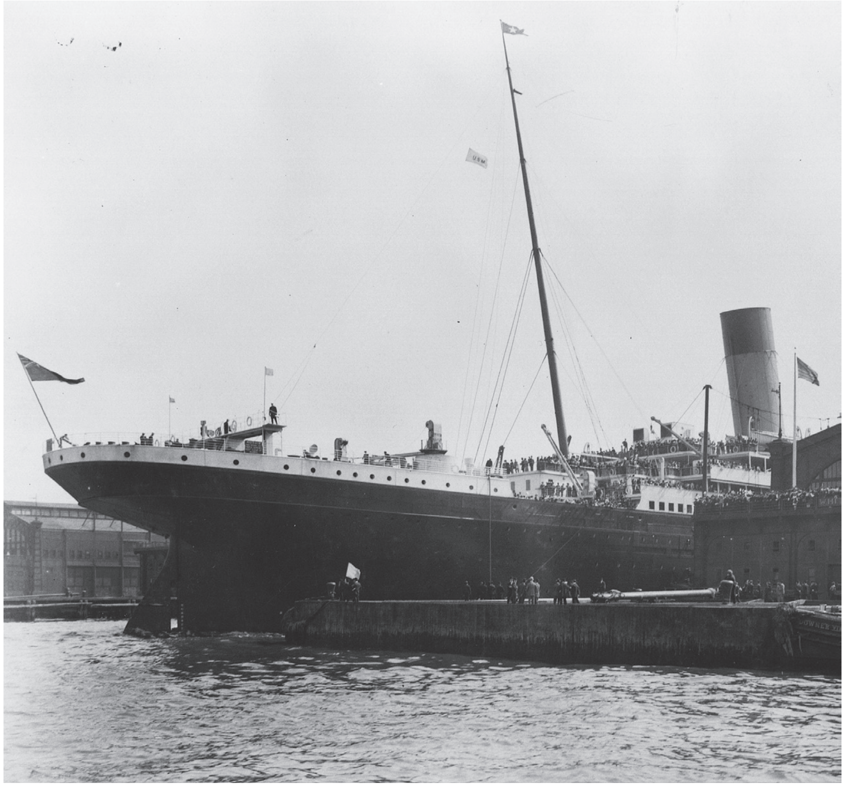


Fig. 22-79 ***Olympic* at New York** – In this image taken at New York, *Olympic* is flying the White Star house flag at the mainmast, the Blue Ensign at the stern, and the US Mail flag. Also seen here are the flagpoles in place on the Docking Bridge, with white flags flying.

> readily connected by inserting a two-pin plug into one side of the box. There is also another two-pin plug fitted on the other side with a short length of cable suitably arranged with a bayonet adapter for fixing into any lamp holder for supplying the necessary current.
>
> The Morse key may be arranged in a watertight brass box with the key projecting through the front. This is substantially made and can be worked by the foot in place of the hand if required.

The manufacturer further explained that the box to which the Morse key was attached had the Morse alphabet engraved onto glass inside the lid. Behind this glass was a small carbon resistance lamp (bulb) that glowed and illuminated the glass from behind. This resistance lamp that illuminated the Morse alphabet from behind worked in reverse with the Morse lamp above. Each time the Morse key was depressed, the illuminating light in the box cut out, and vice versa, so that Morse signaling could be easily done without seeing the Morse lamp above. Moreover, signaling could be easily accomplished by someone with little or no knowledge of Morse code by reference to the illuminated alphabet the manufacturer provided.

The manufacturer closed by noting that:

> This flashing lamp has been thoroughly tested at sea on various steamers during the last twelve months.

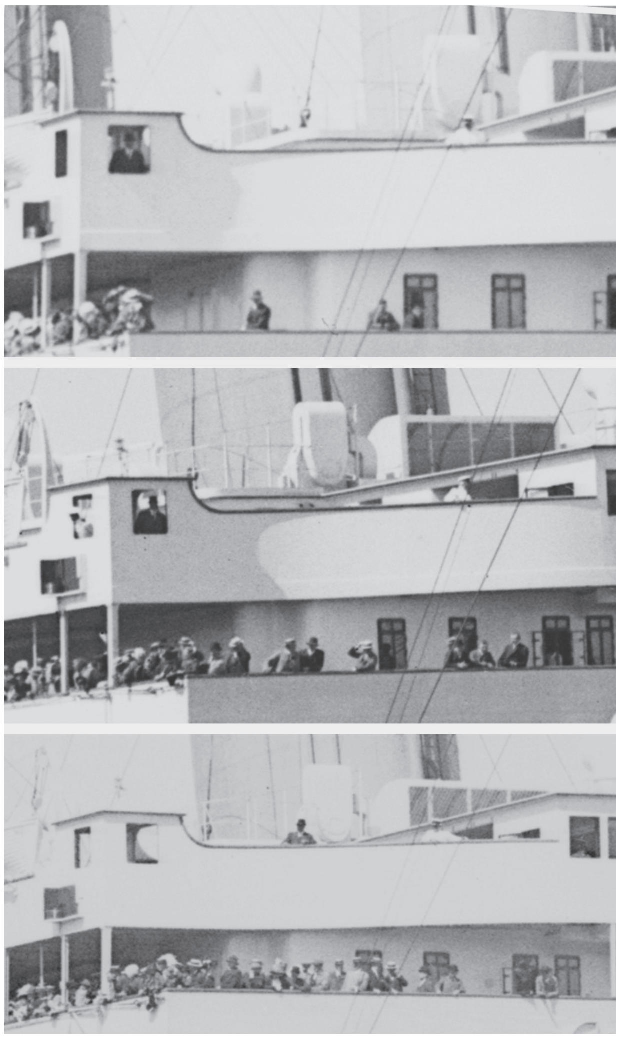


Fig. 22-80 ***Olympic* Docking at New York** – In these three images, *Olympic* is approaching the White Star dock in New York on her maiden voyage in 1911. The man in a suit and hat in the Bridge wing cab is Pilot Julius Adler, and Captain Smith is standing at the bulwark relaying orders to the Quartermaster inside the Navigating Bridge through the open side window.

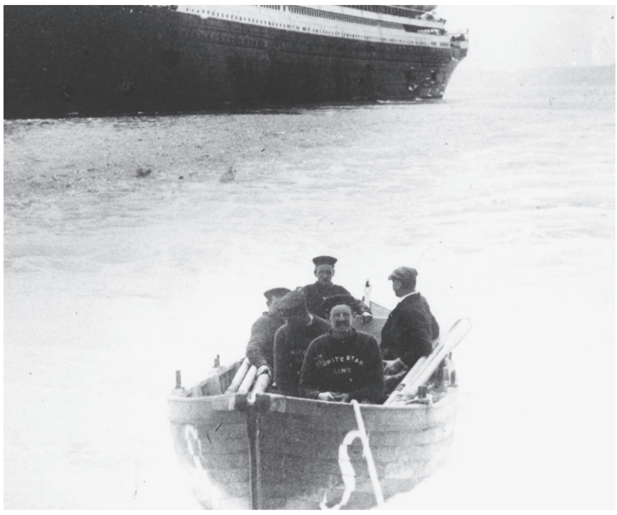


Fig. 22-81 **Pilot Departing *Olympic*** – A pilot (standing at right) after being taken off *Olympic. (Private collection)*

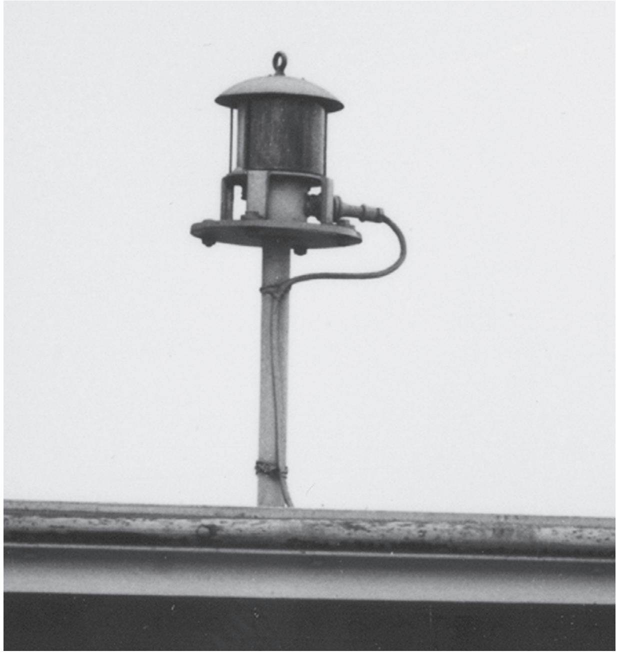


Fig. 22-82 **Morse Lamp** – *Olympic*'s starboard side Morse lamp. The view is looking outward from the Bridge, which may explain the blocked lens seen here. The Morse lamp lenses were very likely shrouded on their inboard sides so as not to temporarily blind the officers on watch by ruining their night vision. *(H&W/Authors' collection)*

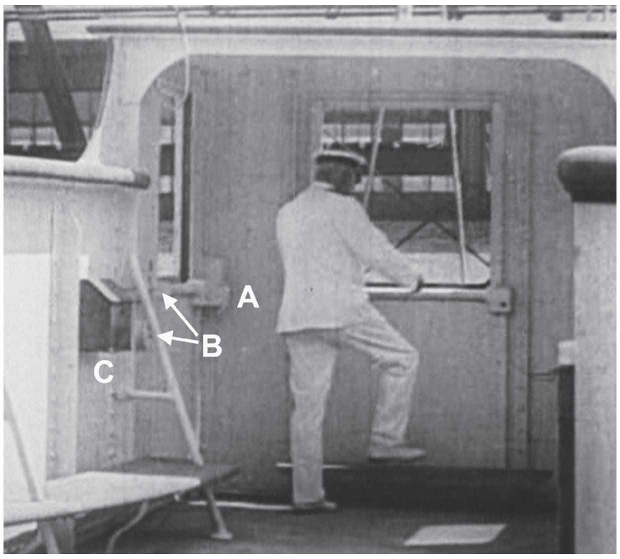


Fig. 22-83 **Bridge Wing Cab on *Olympic*** – In this frame from a 1911 newsreel film, Captain Smith is pictured in *Olympic*'s starboard Bridge wing cab. Inside can be seen a number of instruments: A- Morse lamp key, and to the side, the casting for inserting the operating handle for the sliding window; and B – a set of whistle controllers. Just outside and inboard of the Bridge wing cab is a teak binocular storage box, C. Also, notice the step the captain is standing on.

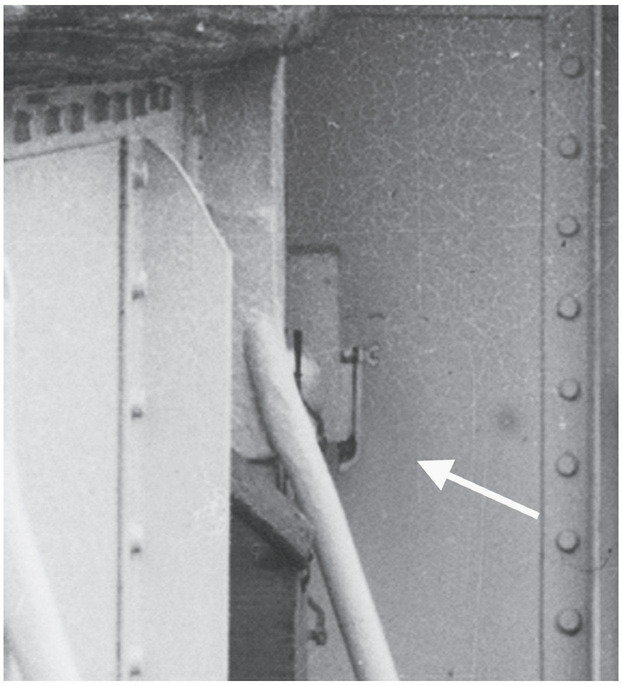


Fig. 22-84 **Morse Lamp Key** – In this enlarged image from the side of the Bridge wing, the Morse lamp key is just visible.

> Signals can easily be distinguished up to a distance of ten to fifteen miles.
>
> The contacts on the Morse key are made of platinum; no condenser is necessary, as the current required for working the flashing lamp is so small. There is no sudden strain put on the filament of the lamp, as there is always a small amount of current flowing through it, sufficient to heat the filament; by this means the filament will stand severe shock without any injury.

Sending messages with the Morse lamps could be done either by spelling each letter individually as by wireless, or by sending message codes as provided for in the flag system. The latter was not recommended as an error in sending or receiving one letter could significantly alter the entire message.

Pyrotechnic and rocket signals

Most routine signaling at night would be accomplished by means of electric Morse lamps, but *Titanic* carried a full range of pyrotechnic and rocket signals in the number and pattern approved by the Board of Trade – e.g., twelve ordinary rockets, thirty-six socket signals in lieu of guns, two Manwell–Holmes deck flares, twelve blue lights (Roman Candles), and six lifebuoy lights. Any mention of night signals must include a discussion of the rockets: they were specific in their characteristics, were used on the morning of April 15 by *Titanic*, and their display was tragically misunderstood.

Article 31 of the 'Rules of the Road' specified a number of signaling devices that could be used in distress at night:

> A gun or other explosive signal fired at intervals of about a minute;
>
> Flames on the vessel (as from a burning tar barrel, oil barrel, &c.);
>
> Rockets or shells, throwing stars of any color or description, fired one at a time, at short intervals;[38]
>
> A continuous sounding with any fog-signal apparatus.

The primary distress signal carried by *Titanic* was a type of rocket that shot aloft with a luminous tail visible, exploding at an altitude of several hundred feet in a burst of white stars or balls. Thus, they could easily be seen by other ships even if they were out of sight over the horizon. While the regulations recognized stars of any color as distress signals, company signals, including rockets – used to identify what shipping line a vessel belonged to – were also color-producing pyrotechnics; and although they did not explode at altitude and produce a burst of stars, the potential for confusion was inherent at great distances. For this reason rockets producing white stars were becoming more prevalent as distress signals, as they were less likely to be confused with company signals. Nonetheless, in order to be interpreted clearly as distress signals, they had to be fired one at a time at short intervals, as specified by the Rules of the Road.

Titanic carried thirty-six socket distress signals which were to be launched from a tube (socket) mounted to a bulwark, the socket being supplied by the product manufacturer to specifically accommodate their signals. The signal was completely self-contained and had a built-in detonator; no separate firing charge or match was necessary. The signal was simply inserted in the socket, and a friction tube inserted into a hole in the top of the signal. A lanyard was then hooked to the top of the friction tube and sharply puled sideways to tear away the loop on the friction tube which, in turn, fired the charge. Nothing remained in the tube after firing and another signal could be fired from the same tube immediately afterward. At least one of these tubes (sockets) was located just abaft the starboard Bridge wing, while a second was located atop the Docking Bridge railing on the port side.

Titanic also carried twelve ordinary rockets. These shot to altitude and displayed a luminous tail. They produced no burst of stars but sounded a loud report. Being similar to the socket distress signals they were cotton powder (nitrocellulose) rockets, manufactured by the Cotton Powder Co. Ltd, London, and were specified to have a minimum of 16oz of composition in them. Generally these type of rockets were used for day signaling in matters of navigation. Although they were not specifically intended as distress signals they could be used as such; section 733 of the Merchant Shipping Act specified that when they were used as distress signals they were to be fired one at a time at intervals of about one minute.

Steamships also had the option of 'minute guns' or explosive rocket signals for distress purposes. In this category *Titanic* carried thirty-six socket signals. These were explosive rocket signals and operated the same as the white rockets discussed above, although they were not intended for night-time signaling as they did not emit stars. Explosive rocket signals did emit a very loud report when detonated, but explosive propellant charges were also used on some ships for firing lines; therefore one or even several loud reports was not necessarily a signal of distress. In order to be interpreted as a distress signal, explosive rocket signals had to be fired at one-minute intervals. They did not produce stars, though, which were a feature specific to signals intended only for distress. They were useful in reduced visibility or when effective signaling could not be carried out by other means. (The white rockets also produced a report while dispersing the chemicals that created the stars, but not as loud as detonating or explosive signals which were a different type of distress signal altogether.[39] The difference is analogous to a modern-day fireworks display, in which the burst charge of a standard color shell does not produce the loud explosive sound of the report shells used for the 'grand finale'.)

Other night signals included twelve blue lights, known as 'flare-up' lights. These were 'Roman Candles', which ejected a ball of fire in blue. They were used for specific signaling purposes as outlined in the regulations, for instance, signaling the need for a pilot at night. It is important to note that these blue lights were not the same as the distress rockets, which emitted stars at altitude. The Roman Candles did not have the height of a distress rocket, and consequently were not visible at long range. They were utilized mainly for shore or harbor purposes.

The Board of Trade also required passenger ships to carry two deck flares, not for distress signals *per se*, but for use at anchor in case another ship came too close, especially in fog. *Titanic* carried Manwell–Holmes deck flares to fulfill these requirements. Deck flares were designed to burn in an open receptacle filled with water, thereby permitting their use on deck. While ships at anchor in limited visibility were required to sound a gong at regular intervals in addition to displaying riding lights as at night, fog could obscure sound as well as the light signals. Deck flares, then, could be used as emergency signals for any unaware vessel that was close aboard. They were to be capable of burning strongly for at least forty minutes, and were self-igniting in water. Full instructions for their use were to be attached to each of them, and suitable receptacles for containing the water required for their combustion were to be provided. (Safety also required a free flow of water around the light if it was to be burned on deck.)

Titanic also carried a quantity of green pyrotechnic lights for use as company signals. White Star Line regulations specified that two of these green pyrotechnic lights were to be burned simultaneously when it was necessary at night to identify its ships as being of the White Star Line. Being waterproof and hand-held, they were similar to the modern road flare. A number of these were burned by Officer Boxhall in his lifeboat on the morning of April 15, one of which was seen by Captain Rostron of the *Carpathia*.

All pyrotechnic signals were to be clearly and permanently marked and stamped with the date of manufacture. They were to be stored in separate, detached and completely enclosed receptacles. These separate receptacles were not to be made merely by divisions or partitions in a cabinet or locker or chest, but were to be separate magazines exclusively dedicated to the keeping of explosives. These regulations were needed in case the contents of one of the receptacles spontaneously combusted. And, as might be imagined, to avoid premature ignition, no article of an explosive or highly flammable character was to be carried in any room or place in which any receptacle containing distress signals was deposited.

Notes

1. The name 'binnacle' – originally 'bittackle' in the early seventeenth century – was originally applied to a small shelter for the steersman.
2. In 1892, Thompson was elevated to the peerage for his numerous achievements, taking for himself the title 'Baron Kelvin of Largs'.
3. The Navigating Bridge was sometimes referred to as the 'Captain's Bridge'.
4. Many ships *were* built with steel decking over their navigating bridges and wheelhouses out of necessity, based on the design of the decks. Compasses could be adjusted for this overhead steel, but it was far more preferable if this steel was eliminated altogether. One must remember that even submarines carried magnetic compasses.
5. In modern-day navigation terms, we would say that the true course was 266°, the standard course was 287° and the steering course was 289°.
6. Much of the information in this section has been drawn with permission from the website of Dave Gittins at http://users.senet.com.au/~gittins/navigation.html
7. The term 'dead reckoning' is believed to derive from 'deduced reckoning,' which was abbreviated to 'de'd reckoning' in many early naval logbooks.
8. Captain William Turner of the *Lusitania* was faulted by some for taking a four-point bearing off the coast of Ireland before his ship was torpedoed, during which the ship had to hold an unwavering course for some forty minutes while the necessary observations and calculations were made.
9. The time at the zero meridian is known as Greenwich Mean Time because the zero line of longitude passes through the Royal Naval Observatory at Greenwich, England.
10. Although the servicing of timepieces is not done by opticians today, in 1912 they were serviced by opticians.
11. One of the claimed properties of this was that it repelled large fish, which had been in the habit of swallowing earlier logs!
12. Although *Titanic* carried a log of the 'Neptune' model, the deck crew referred to it as the 'Cherub log' because that is what this type had become known as, even though the model name had changed through the years with upgrades in design.
13. On the night of *Titanic*'s sinking, the last water temperature was taken by Quartermaster Robert Hichens just after 9.45 p.m.
14. A commutator is more properly a device making up part of an electric motor; however, the term was and still is used to identify a clinometer in some areas.
15. Diameters quoted for the glass dials are from a February 27, 1914 article in *Engineering* written about *Titanic*'s sister ship *Britannic*, and have been corroborated based on measurements taken of telegraphs raised from the *Titanic* wreck. The dimensions in the text following that are noted as approximate are based on the same measurements.
16. With the exception of the outboard main engine telegraphs, the specific identification of the Bridge telegraphs (as to which telegraph performed which function) has never been definitively established by builders' records or other evidence; they reflect current thinking based on evidence from various sources, although these have not been examined personally by the author.
17. Frequently, in working the telegraph, the handle would be brought past the position desired and then back to it, in order to ring the bell not once but several times. In the initial 'over-ring' motion, it was recommended that officers not ring past the center ('STOP') position into the opposite area of the dial, instead confining all movement to the side of the dial the order was on. In this way, should the telegraph linkage part before the handle was brought to the position of the order desired, an order would not inadvertently be given to reverse the engine(s).
18. Pollard, Captain W.F. *Daily Steamship Duties*, (Glasgow: James Brown & Son, Nautical Publishers, 1924.) *(Art Braunschweiger collection)*.
19. These were more formally known as the Regulations for Preventing Collisions at Sea, and were agreed upon by all the major countries of the world. Today they are known by the abbreviation 'Col Regs'.
20. It should be noted that the 'Rules' did not define 'under way' as being in motion; any vessel not moored or not at anchor was to be considered under way.
21. There has been much debate over the existence of this supposed light and the credibility of Mrs Shutes' assertion. However, as the lens within this type of light was designed to project light outward in a horizontal plane, these lights could often appear quite dim if not viewed directly in line with the center of the lens and the source of illumination within.
22. The term 'sidelights' here should not be confused with those sidelights fitted within the hull to admit light and provide ventilation to interior spaces.
23. It is interesting to note that Mr W.J. Willett-Bruce, inventor of the whistle control device, was Superintendent Engineer of the White Star Line.

24. Ships at anchor during fog or significantly reduced visibility were required to sound a gong or bell at intervals of one minute.
25. The white star of the house flag was actually sewn over a star-shaped cut-out in the field, and because the overlap necessary for stitching was not visible from the other side, the star appeared slightly smaller on that side.
26. This is supported by White Star Line regulations, which called for shorter flags to be flown in stormy conditions.
27. The US ensign flown by *Titanic* had forty-six stars. Although the addition of Arizona and New Mexico in January and February of 1912 had increased the number of states to forty-eight, the flag was not changed until July 4 of that year.
28. The French ensign is nearly identical to the version flown on land, but the proportions of the blue, white and red stripes are unequal in the ratio of 30:33:37; this gives the appearance of equal proportions when flying.
29. Unofficially, the Red Ensign was widely known as the 'Red Duster'.
30. Some photographs indicate that the masthead flags were left in place for the duration of the Channel crossing, with the foremast flag changed over to the French 'tricolor'. This was evidently the case with *Titanic*, as a photograph taken just before the open waters of the Channel show all flags still in place.
31. Although the Merchant Shipping Act of 1894 permitted use of this flag when dressing ship, it did so by description and not by name. The term 'Merchant Jack' is also applicable, although more generic. As period editions of *Brown's Signalling* referred to this flag in illustration as a 'Pilot Jack', that term has been used here.
32. During the First World War, *Olympic* would have her signaling capability increased by the addition of a third and fourth halyard to the signal stay above the bridge, plus a second signal stay between the first and second funnel, this second stay carrying two additional halyards.
33. Numeral flags had been in use in British Naval signaling since 1790, but in 1912 they did not yet exist in the International Code.
34. Distinguishing Signals were always four letters. Merchant ships' distinguishing signals always began with 'H' or any succeeding letter; naval ships' distinguishing signals always began with the letter 'G.'
35. A pilot is an individual knowledgeable of local currents, channels, tides, and other factors influencing navigation and vessel handling in confined waters and channels.
36. Southampton Pilot George Bowyer piloted both *Titanic* and *Olympic* on their maiden voyages.
37. The Pilot flag was also flown from the mast of a vessel in the pilotage service with a licensed pilot aboard – in short, it functioned to help identify a pilot vessel.
38. Testimony given at the British Inquiry established that *Titanic* fired eight rockets from approximately 12.45 a.m. to 1.45 a.m.
39. Boxhall described the rockets he fired as 'the socket distress signal.' This term, while correct as a general description, did not necessarily mean that they produced an explosive report. There were rockets that produced stars in addition to an explosive report, but the rockets carried by *Titanic* were not of this type.

Chapter 23

Lifeboats, the Welin Davit and Safety Appliances

While the general subject of *Titanic*'s lifeboats has been written about a great deal, technical descriptions of the lifeboats have been sparse. There are no known surviving plans of *Titanic*'s sixteen open boats, and it is probable that there never were any as this type of boat was usually built 'to the eye' with a mere midship mold. However, it is known that lifeboats were built to specifications set forth by the Board of Trade, and a surveyor would have inspected the boats on many occasions while under construction to ensure that the specifications were followed.

Titanic's lifeboats were the 'double bow', or 'double-ender' type, and were supplied with the equipment required by the Board of Trade at the time. It should be understood, however, that being 'supplied with' and being 'fitted with' were two different terms. For instance, even though the lifeboats were supplied with spirit compasses, they were not stowed in the boats, but instead in a locker on deck, and were never placed in the boats prior to their being launched on the morning of April 15. Compasses were not stowed in the boats, not only because they were fragile instruments, but to avoid a common form of theft at the time. All brass fittings not screwed down were put under lock and key, and this included the lanterns as well.

In March 1886, a Departmental Committee was appointed by the Board of Trade to inquire into the question of boats, rafts, and life-saving apparatus carried by seagoing merchant vessels. Though the rules were updated a few times after 1886, and more specifically from 1894 to 1906, they fell considerably short of addressing vessels the size of *Olympic* and *Titanic*. In 1912, *Titanic*'s lifeboat accommodations complied with current regulations, which specified that vessels over 10,000 tons with approved watertight subdivisions were to have sixteen lifeboats.

There were twenty lifeboats carried aboard *Titanic*, divided among three types of boat. The majority were the main 30ft open boats of which there were fourteen, classified under Section A of the Board of Trade regulations; these lifeboats each hung in their own pair of Welin davits. There were two 25ft cutters classified under Section D of the regulations; these were similar to the main lifeboats, but smaller. The two cutters – also called emergency or 'accident' boats – were carried near the Navigating Bridge, one on each side of the vessel, swung outboard of the ship's rail while at sea and ready for immediate use. In emergencies such as persons falling overboard, these boats could be rapidly manned, gripes slipped, and lowered into the water at the word of command from the officer in charge on the Bridge. Special men, usually two Quartermasters, were selected for manning these particular boats, this number being sufficient for proper handling and navigation. As the necessity for lowering these boats usually occurred when the vessel was under way with considerable speed, it was necessary that the men managing these boats should be well trained and proficient.

To provide additional capacity, *Titanic* was equipped with four 'Engelhardt collapsible lifeboats'[1] which fell under Section E of the regulations; these were similar to a wooden raft with canvas sides that were raised when the boat was needed. The Engelhardt collapsibles were stowed on the Boat Deck below the cutters and on the roof of the Officers' Quarters deckhouse. With the four collapsibles added, *Titanic* actually exceeded the lifeboat capacity required of her under current regulations.

The Engelhardts were new to the crew. At the post-sinking Board of Trade investigation into the loss of *Titanic*, it was found through their testimony that they did not know how to work them for the most part. In fact, the crewmen who were questioned about the Engelhardts did not consider them 'collapsible' at all, as they were not the same as the true collapsible such as 'Berthon' boats that these men were familiar with. While the Berthons were completely sheathed with canvas and folded in half longitudinally, the Engelhardts were part plank and part canvas. The only collapsible detail was the canvas bulwarks.

Dimensions and Capacities

Various metal identification plates were attached to the exterior of *Titanic*'s boats. The 30ft and 25ft boats had metal boat numbers applied to the forward and after ends, port and starboard, 2½ to 3in in height. These sixteen boats were assigned numbers according to their position on deck. Starboard boats were odd-numbered and port boats were even-numbered. The numbering started with the forward-most starboard boat which was number '1' and the forward-most port boat as number '2'; from here, the numbering continued, alternating from starboard to port, proceeding aft. At the forward and after ends, a name plate with raised letters 'S.S. TITANIC' was applied to the outboard side, and the port of registry (LIVERPOOL), was applied on the inboard side of the boats. These words were cast into brass plates 12in in length. White Star Line flag plates were also applied forward and aft on both sides, and draft plates with 7/8in lettering identifying length, breadth, depth, and capacity were applied to the forward inboard side.

There is no indication that the Engelhardt collapsible boats had any external identification. However, these four boats were identified as 'A', 'B', 'C', and 'D'. On the roof of the Officers' Quarters deckhouse were Collapsibles 'A' (starboard side) and 'B' (port side). Collapsible 'C' was on the Boat Deck under the starboard emergency cutter and 'D' was on the Boat Deck under the port cutter.

The sizes and capacities of the various boat types, as indicated on the plates affixed to the boats themselves, were as shown in Table I below.

Table I – Lifeboat Dimensions and Capacities Indicated on Lifeboat Identification Plates

Description	Measurements	No. of Persons per Boat
14 Open Lifeboats	30ft 0in x 9ft 0in x 4ft 0in	64
2 Wood Cutters	25ft 0in x 7ft 0in x 3ft 0in	33
4 Decked Lifeboats	28ft 0in x 8ft 0in x 3ft 0in	40

Boat Construction

The open boats and cutters were designed by Chief Draughtsman Roderick Chisholm and built in Harland & Wolff's own Boat Shop. The materials were the same between each, the only variations being that the sizes of the individual components were adjusted to the different dimensions of these two classes of boat. For this writing, we will address the general construction of a 30ft lifeboat. The slight differences in the cutters will be addressed separately.

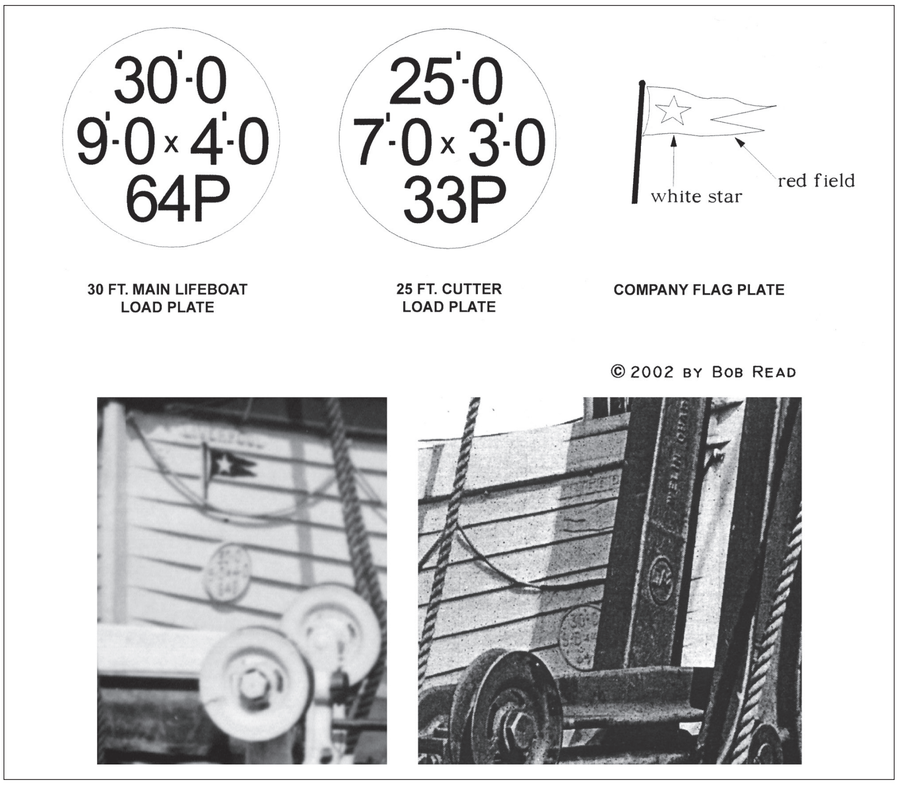


Fig. 23-1 **Lifeboat Load Plates**. *(Illustrations by Bob Read; images from authors' collection)*

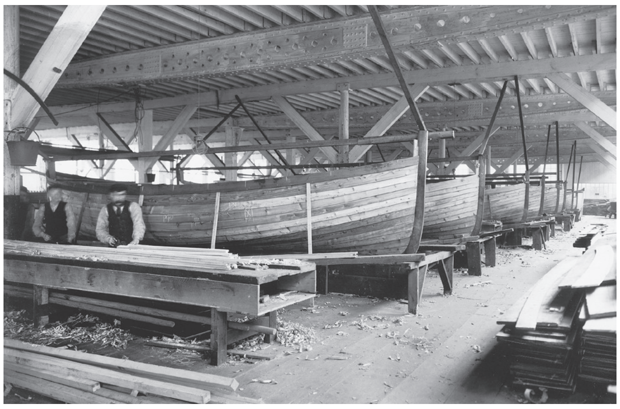


Fig. 23-2 **Boat Shed at Harland & Wolff** – A photograph of the interior of Harland & Wolff's Boat Shed contemporary to *Titanic*'s era. *(*The Engineer*/Authors' collection)*

The different parts that went into a lifeboat, such as the thwart knees, breasthooks, etc., were constructed from dimensions that were more or less standard based on the length of the boat. It was known that a certain length of lifeboat, along with its corresponding breadth and depth, would require parts built to a predetermined strength. The same was true for lifting hooks and sail areas as both were based on the size of the lifeboat. However, the two main factors in constructing a good lifeboat were seasoned material and honest workmanship. There were many instances recorded in the years prior to 1913 where builders cut corners in construction resulting in unreliable lifeboats and crewmen who did not trust loading a boat to the stated full capacity.

Since there are no surviving plans of the fourteen main lifeboats and two emergency cutters, details beyond basic dimensions have to be gleaned from contemporary images and general references. Some of the best views of the interiors of the boats are from the post-disaster photographs taken at New York. Interior details of the emergency cutters can be seen in a photograph of one of them being hoisted aboard the *Carpathia*. There are general plans of Engelhardt collapsibles available in period reference books, but interior photographs of

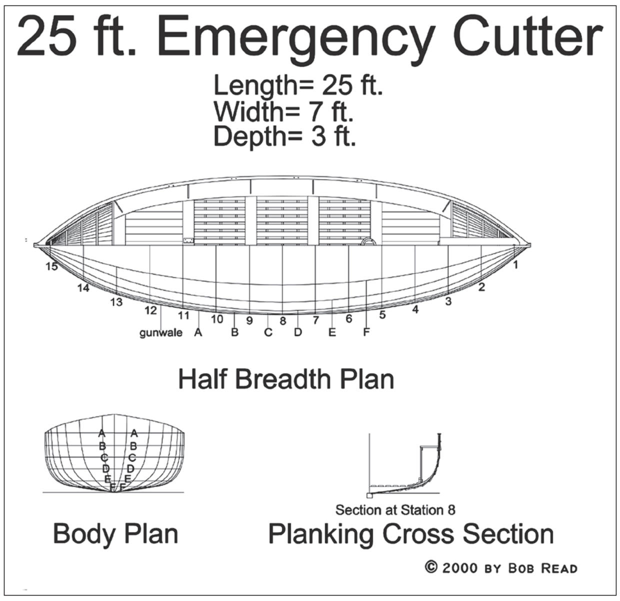

25 ft. Emergency Cutter
Length= 25 ft.
Width= 7 ft.
Depth= 3 ft.
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
gunwale A B C D E F
Half Breadth Plan
A B C D E F
Body Plan
Section at Station 8
Planking Cross Section
© 2000 BY BOB READ

Fig. 23-3 **25ft Emergency Cutter.** *(Illustration by Bob Read)*

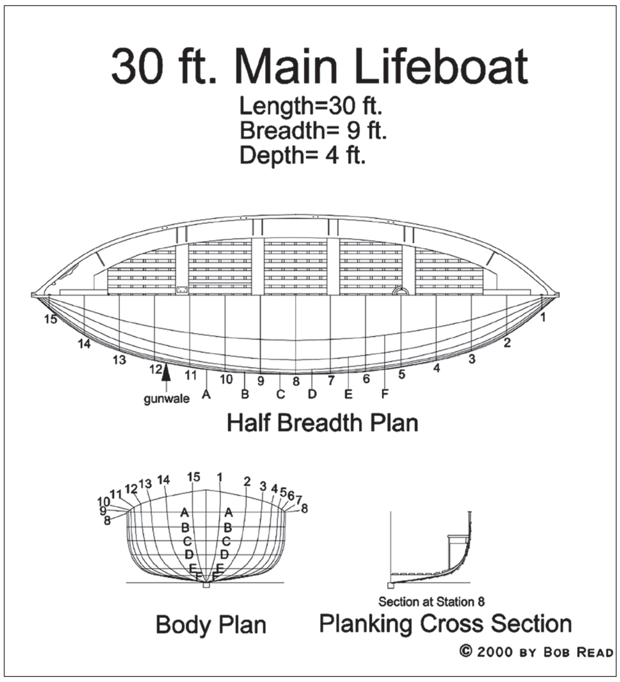

30 ft. Main Lifeboat
Length=30 ft.
Breadth= 9 ft.
Depth= 4 ft.
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
gunwale A B C D E F
Half Breadth Plan
10 11 12 13 14 15 1 2 3 4 5 6 7 8 9 8
A B C D E F
Body Plan
Section at Station 8
Planking Cross Section
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Fig. 23-4 **30ft Main Lifeboat.** *(Illustration by Bob Read)*

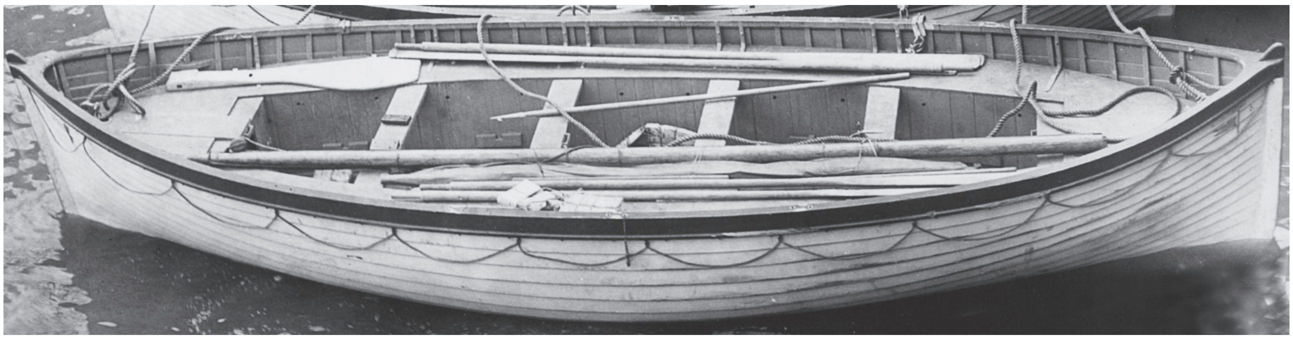
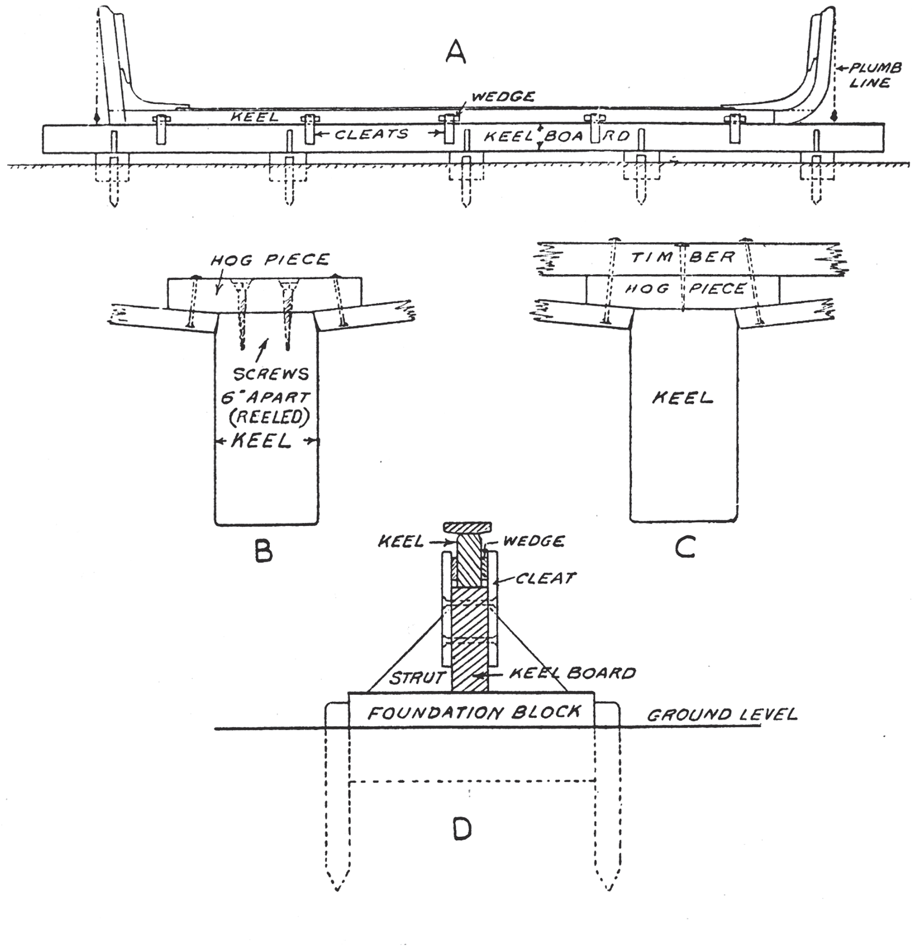


Fig. 23-5 **30ft Main Lifeboat** – One of *Titanic*'s 30ft main lifeboats as seen at New York after being offloaded from the *Carpathia*. *(Josha Inglis collection)*



A, arrangement of keel boards and foundations.
B, method of securing hog-piece to keel and garboards.
C, method of securing timbers to hog-piece and garboards.
D, section of keel board arrangement.

Fig. 23-6 **Arrangement of Keel Boards** – At top (A) and bottom (D), A keel board and foundation arrangement similar to what was used at Harland & Wolff. This is how the lifeboat construction started. At center left (B), a cross section of the keel with the hogpiece fitted. At center right (C), a crosssection showing one of the timbers resting on the hogpiece. The keelson is not shown here. *(Ship's Boats/Authors' collection)*

Titanic's Engelhardts are lacking. Unfortunately, no rigging plan has survived for any of the boats.

Framing[2]

The foundations, or what were generally referred to as the 'keel boards', were made from sound and substantial 6in x 3in American Elm. The keel boards were not part of the boat, but served as a base upon which the keel rested as the boat was constructed. In beginning construction, the keel boards were first tied to good, heavy foundation blocks, anchored in the ground and prevented from movement by piles or stakes. The blocks were arranged at short intervals under the keel boards to prevent hogging or sagging.

The keel was in one length and selected from wood that was straight in the grain, as objectionable knots and swirls were carefully avoided. The keel was placed on the keel boards and kept perfectly straight in a fore-and-aft direction by driving in wedges between the keel and cleats attached to the keel boards. The top edges of the keel were chamfered to enable the garboard strakes to have a square landing edge; this work was carefully performed to provide a satisfactory seam for caulking.

The combination between the stem, sternpost, and keel was well-built and strong, and the wood used was of the best quality. The stem and sternpost were of English Oak, 5in x 2½in. The connections between the keel and the stem and sternpost were made by a vertical scarf which was preferred over the horizontal scarf because of its strength. A deadwood piece was then fitted to the inner side of the scarf and fastened through to the keel and stem with stout bolts.

The full thickness of the keel was preserved out to the face of the stem, with the bearding arranged to commence from about 4in above the top of the keels with an easy curve. The bearding was 1½in in breadth on the face of the stem in the 30ft open boats and about 1in in the smaller boats. When the connections had been completed and fastenings properly clenched, the stem and sternpost were made plumb and the heads were secured by shores to some permanent part of the boat shed.

To provide a good landing edge for the garboard strakes and a solid connection for the timbers, a 'hog-

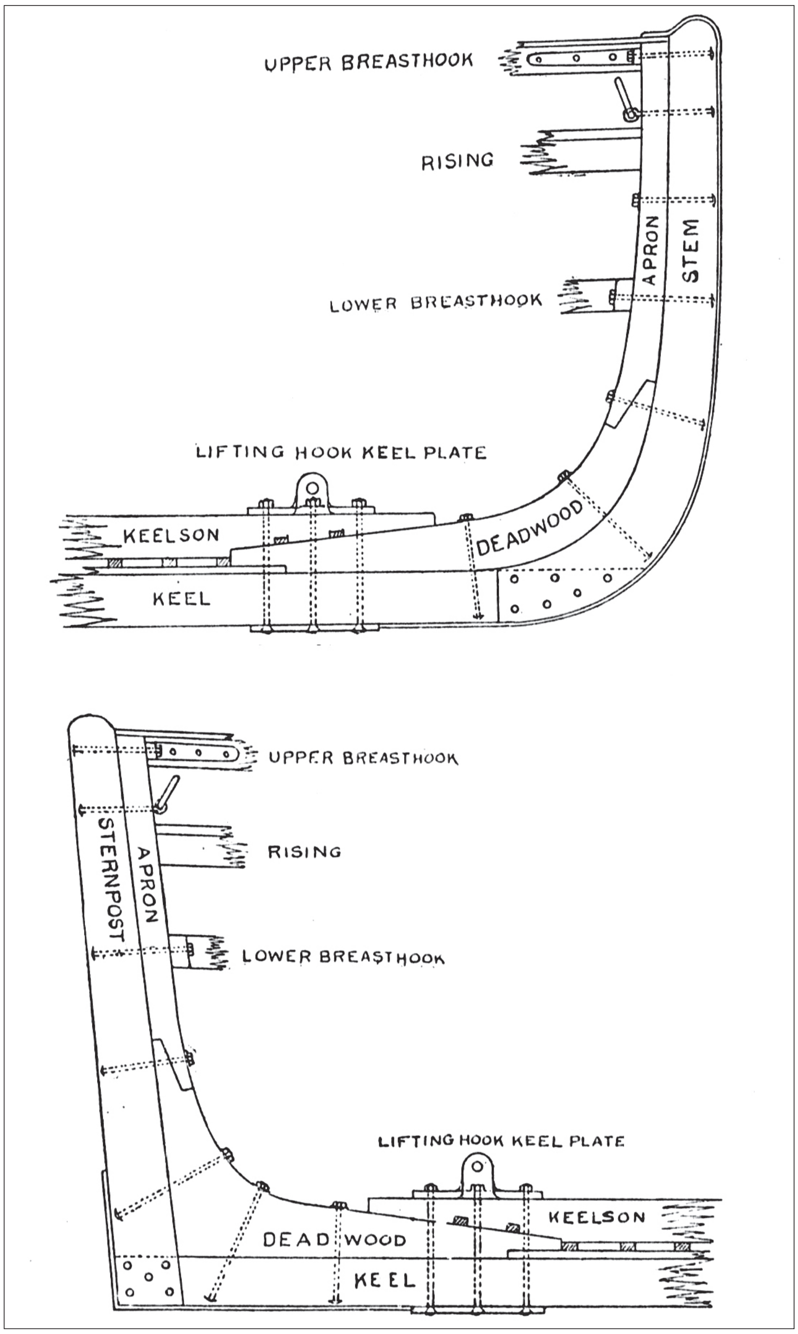


Fig. 23-7 **Stem and Sternpost** – These two illustrations show the stem and sternpost as well as the keel, keelson, deadwood, apron, upper and lower breast hooks, rising, and the means by which the lifting hook was secured to the keel. *(Ship's Boats/Authors' collection)*

piece' was worked in one length on top of the keel and checked under the deadwood. The material was American Elm of straight grain, free from shakes, and 1in thick to ensure a solid foundation for the caulking seam. The hog-piece was secured to the keel by stout screws about 2½in in length and 6in apart. The width of the hog-piece was 5¼in and was arranged to provide a good bearing for the garboard plank landings and the timber fastenings. The operation of clenching the timber fastenings through the hog-piece was undertaken at the first opportunity, and before the keelson was in position.

The spacing of the timbers governed the pitch between the keelson fastenings and was generally in 9in intervals. The whole of the fastenings, in conjunction with the position of the timbers, were marked in position on the hog-piece, and the latter was temporarily secured in position on the keel.

The deadwoods formed a solid strut to the stem, sternpost, and keel, distributing the stresses to the frames of the boat which were received through the lifting hooks. The form of the deadwoods received the maximum amount of support from the timbers, planking and combinations; they were sided to preserve a full faying surface for the reception of the planking. This provision also provided the advantage of preventing the accumulation of water and dirt between the planks and deadwoods; this was an important matter as the deadwoods were located at the ends of the boat, covered in and rarely inspected.

Faying surfaces of 3 to 3½in were preserved for the double fastenings at the plank landings, or 'hood-ends'. It was permissible to fill in the intervening space between the deadwoods and planks with filling pieces, efficiently secured to the deadwoods before the planking was worked. These filling pieces were well bedded in thick, white-lead oil paint.

It was usual to arrange for five through-fastenings in each deadwood piece, the upper one forming the scarf connection to the aprons. When boats were lifted at the extreme ends, as was done with the Welin davit, it was necessary to pitch the fastenings to enable them to be incorporated with the keel plates of the lifting hooks.

The apron was that portion of the frame combination which was attached to the stem or sternpost and provided the surface for securing the hood-ends of the planking. Oak or elm was usually employed and care was taken to cut the aprons to shape and preserve sufficient material for fitting the hood-ends of the planks. The fastenings of the apron to the stem and sternpost were similar to those which passed through the deadwoods. The upper bolts were fitted through the stem, apron and gunwale breasthooks; the second was the ringbolt to which the painters were attached. The third bolt passed through apron and stem, but the fourth one usually picked up the lower breasthooks in boats of 24ft in length and upwards. The fifth bolt formed the fastening between the apron and deadwood scarfs with the stem or sternposts.

When the combinations had been fitted, secured, and the frames of the boats made to outwind and plumb the centerlines, they were secured in position at the keel boards and to some permanent part of the boat shed. The positions of the timbers were marked on the stem and sternpost. Before the planking was commenced, it was usual practice for the keelson to be cut to length. The keelson was an essential part of the structure and acted as a very substantial support for the heavy load of a fully equipped boat. It was 5in x 3½in pitch pine, arranged so that its depth was greater than the width, which allowed for greater strength in a longitudinal direction. The keelson extended in one piece as far forward and aft as the combinations allowed and became incorporated with the fastenings of the deadwoods and keel. The keelson was worked to take the fastenings of the lifting-hook keel plates, which gave additional support to the boat. At this period of the construction of the boat, it was only necessary to cut the keelson to length and at the ends to the form of the deadwoods. It was finally placed in position when the boat had been planked and timbered, but before the thwarts were inserted.

It was the common practice among boat builders to take the path of least resistance and simply fit the keelson on top of the timbers. This method allowed free drainage from one side of the boat to the other. However, the most effective means of binding the backbone of the boat and giving better support to the mast-step was to notch, or 'check' the keelson over the timbers so that its lower surface fayed with the upper surface of the hog-piece, the depth of the keelson being increased to allow for the checking.

Planking

The planking used on *Titanic*'s lifeboats was fastened on the 'clinker' method. Each plank ran in a fore-and-aft direction, the edges being lapped, or 'landed' one on the other, the breadth being usually about 7/8in, but no less

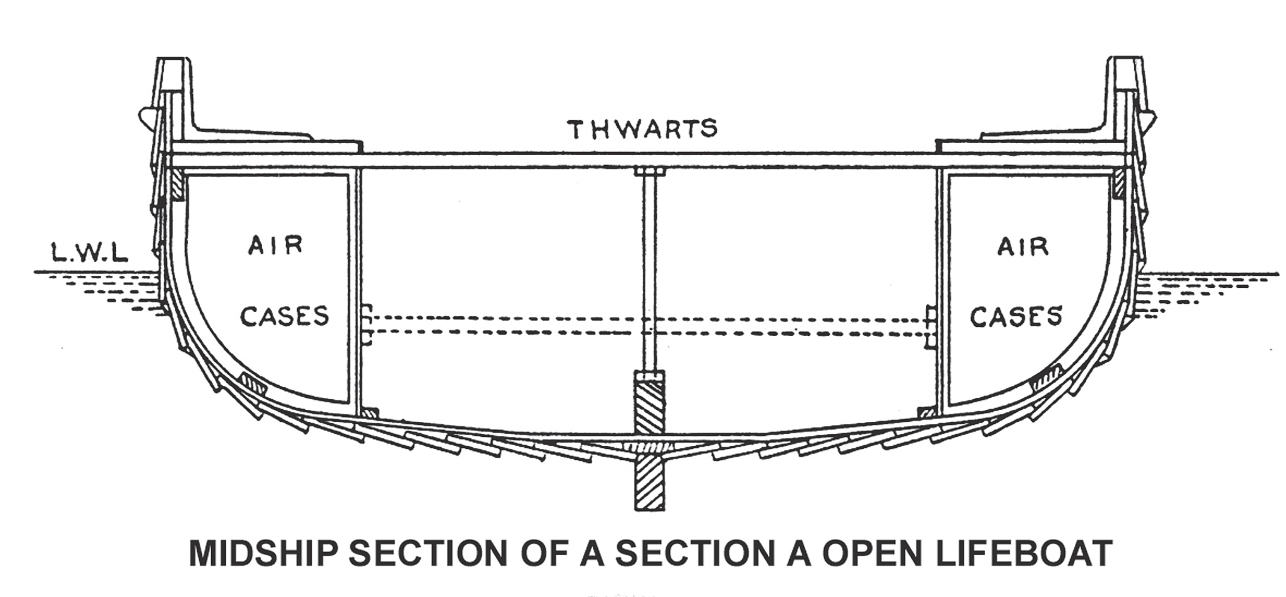


Fig. 23-8 **Midship Section of an Open Lifeboat** – This midship section of a Section A open lifeboat shows the aircases under the side seats. *(Ship's Boats/Authors' collection)*

than ¾in. Boats constructed in the clinker fashion were easily repaired. Simplicity of design and construction, coupled with speedy delivery and a minimum of cost, were the main reasons why the majority of lifeboats supplied to merchant vessels were built on the clinker method. *Titanic*'s lifeboat planks were yellow pine consisting of 5/8in-thick strakes, while the garboard strakes of planking adjacent to the keel were teak. Yellow pine made for a very good boat provided the vessel did not trade in climates of great heat. It was much lighter when compared to other woods, and was known to very quickly 'take up' when placed in the water.

The planking began with section molds being prepared and secured in position. The positions of the planks were then marked on the midship mold and on the stem and sternpost after the standard allowance for sheer had been taken into consideration. The usual sheer recognized in boat yards was one-half inch to the foot. The breadth of the planks did not exceed 5½in, with the exception of the garboard and its adjacent strake which were permitted to exceed this limiting breadth up to 7in. There were 14 strakes per side on *Titanic*'s 30ft boats and 12 on 25ft boats, excluding the sheer strake.

The garboard strake, sometimes called the 'sand-strake', was the first plank adjacent to the keel and was worked from the sternpost, forward to the stem, so that the outer edges of the scarf butts lay aft and were thus protected when the boat was moving forward through the water. The garboard planks required careful fitting at the ends of the boat and, together with the adjacent planks, had a great influence on the rest of the planking as to maintaining a good form.

The planks were held in position ready for securing by the aid of clamps or tongs. The rooving and clenching of the timber fastenings from the bilge to keel was a double-handed process, one person holding on the head of the nail with a fairly heavy and flat-headed hammer, while the roove was driven home and the nail clenched from the inside of the boat by another person. The planks were fastened with flat-head copper nails of 12 SWG.

Careful attention was given to the method of forming and securing the hood-ends of the planking. With at least 3in of faying surface on the apron and deadwood, ample bearing was given for the double row of fastenings. Copper nails were placed in the row nearest the rabbet to provide for good security when caulking the hood-ends; the inner row was also copper nails. It was not sufficient to simply chamfer off the edge of the stem or sternpost to house the hood-ends of the planks. A proper rabbet was to be taken out, leaving at least 3/16in of solid wood so that the plank could take a bearing on the stem and sternpost; this provided an efficient caulking seam. In order to facilitate ease in replacement of the stem or sternpost, the apron was utilized as the point where the hood-ends were fastened.

Common practice was to cut the rabbet for the sheer strake beyond the ordinary plank rabbet so that the former became a means of protection to the remaining hood-ends. The method of completing the hood-ends was to chamfer, or 'snap', the top of every plank; the plank landings were half checked providing a proper bearing for the screw fastenings and the whole of the planks were well secured together.

The planks at the turn of the bilge were kept as narrow as possible to minimize the amount of soleing taken off the landing edges, but leaving sufficient size to allow the upper plank to lie well into the timber

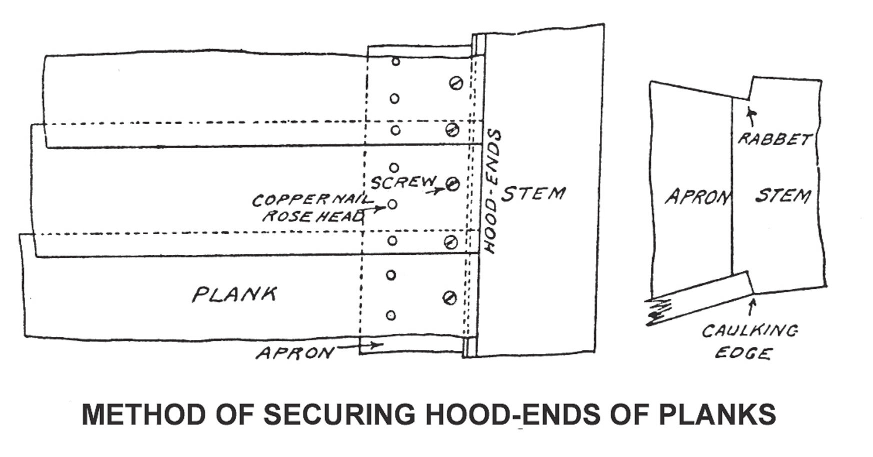


Fig. 23-9 **Hood-Ends** – This illustration shows how the stem was rabbeted to accept the plank ends, or 'hood-ends,' and how the hood-ends were secured to the apron. *(Ship's Boats/ Authors' collection)*

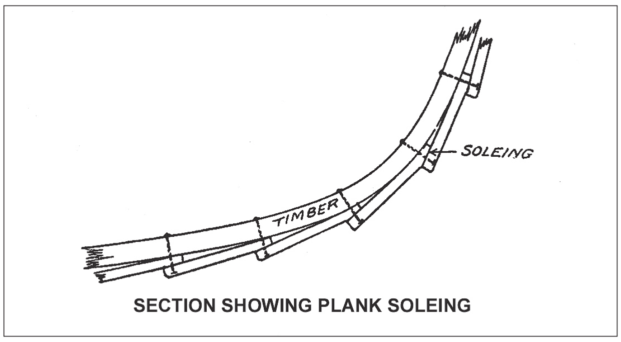


Fig. 23-10 **Section Showing Plank Soleing**. *(Ship's Boats/ Authors' collection)*

without unduly reducing its thickness. The use of section molds facilitated the operation. As each plank was worked, the landings were well-coated with oil paint or a composition called 'blair' which was made of flocking and Stockholm tar. As soon as the planking was in a condition to receive the timbers, the inside surface was given a good soaking coat of white-lead paint or boiled linseed oil.

Timbers

The timbers served the same purpose as the frames in *Titanic*'s hull, acting as the ribs of the boat. The distance between the timbers from center to center was generally 9in. The positions of the timbers were marked on the planking from the indications given on the hog-piece – and also those of the rising and bilge stringer – to enable the sliver pieces between them and the timbers to be tacked in their correct position. It is at this point that the tapered liner behind the sheer strake was fitted in place with a 'box' type of gunwale. Also at this point, all doublings fitted to the planking were checked to ensure they were fastened and clenched, and the planking was deemed to be in a condition to receive the timbers. The timbers at the ends of the boats were spaced slightly less than 9in apart to allow for the flare-out at the gunwale; the heels of those which could not be worked in one piece across the middle line were checked into the deadwood.

The timbers were 1¾in x 7/8in, made from American Elm owing to its close, straight grain and elastic nature, with the timbers rounded on one side. This gave a much lighter appearance to the boat and while preserving the full faying surface of the timber. The extra cost of rounding the timbers was minimal as the process was quickly performed by a spindle machine or by special cutters inserted in the planing machine.

The timbers were placed in a steam chest to soften them up before bending and were then fitted in one length from gunwale to gunwale. The operation of timbering commenced amidships and worked to the ends so that those which were broken during the operation of bending could be worked in at the extremities of the boat where shorter lengths were suitable. The holes were drilled with a bit through the plank landings from the inside of the boat, care being taken (especially at the turn of the bilge) to keep the bit square to the surface of the plank; if not square, the timber fastening would be too close to the landing edge. The nails were inserted in the planks in readiness for the timbers when brought from the steam chest. The timbers were secured at the center of the hog-piece by a galvanized iron nail, and carefully worked towards the gunwale. They were plied over on the inside surface of the timber while the latter was soft and pliable. The timbers were then fastened to the planks with copper nails. Additionally, *Titanic*'s lifeboats were fitted with 3in x 1¼in floors at every timber, extending across the keel as high as the turn of the bilge on either side.

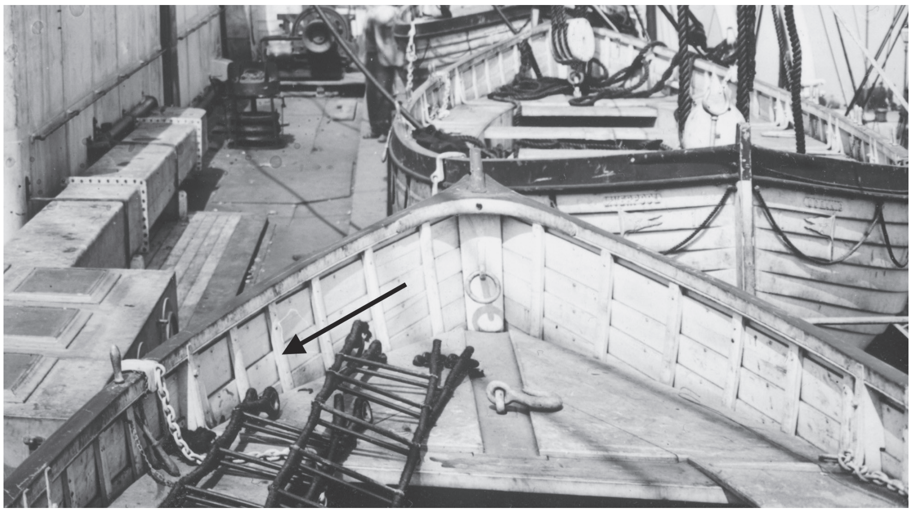
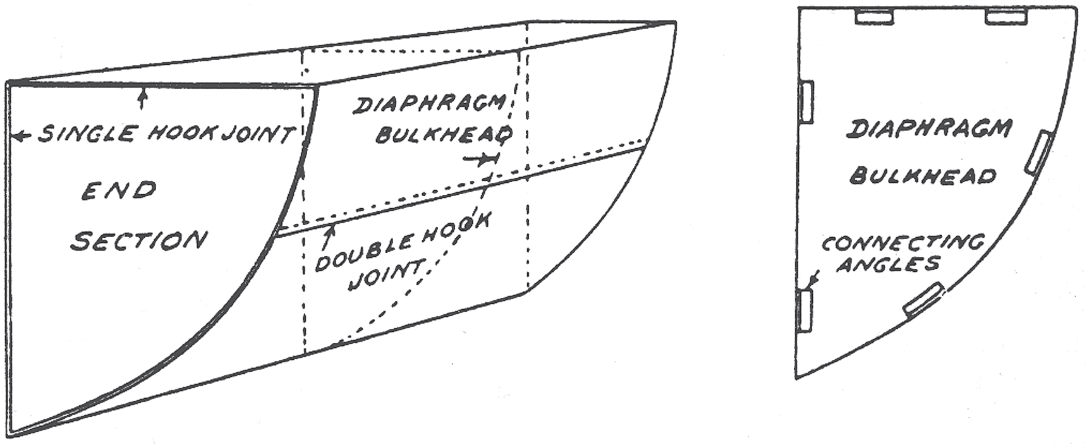


Fig. 23-11 **Timbers on Lifeboat** – In this image of one of *Oceanic*'s lifeboats, one of the timbers is indicated with the black arrow. Attached to the back side of the sternpost is a ring for the painter, and forward of that, extending up through the gangboard, the one of the two lifting hooks by which the boat was raised and lowered. *(H&W/ Authors' collection)*



CONSTRUCTION OF METAL BUOYANCY AIR-CASES

Fig. 23-12 **Air Cases**. *(Ship's Boats/Authors' collection)*

Internal fittings

The 'rising', or 'wearing', was the upper stringer which ran fore-and-aft from the stem to the sternpost apron, forming a seating for the ends of the thwarts and acting as a longitudinal stiffener to the timbers and distributing the stress which came upon the thwarts from the oarsmen or mast. They were generally 4in x 1in, made of elm and fitted in one length. Tapered liners were secured between the timbers and planking; the liners provided a solid bearing for the fastenings. The risings were secured at every timber and to the planking by copper nails clenched over rooves and worked in reel fashion. The backs of the risings, serving as faying surfaces to the timbers, were painted before being secured in position.

Buoyancy air-cases

All lifeboats have a source of reserve buoyancy. *Titanic*'s open lifeboats were fitted with buoyancy air-cases along their sides; these were constructed of the best-quality copper, not less than 18oz to the superficial foot, and were placed along the sides of the boats under the side benches. The size of the copper metal sheets supplied to the tank makers was usually 4ft x 3½ft and weighed 25.2oz to the superficial foot, thereby exceeding the Board of Trade's 18oz minimum specification. The amount of buoyancy-tank capacity on an individual boat depended on cubic capacity and was to provide at least 3 cubic ft of air-case for each person.

Thwarts (seats)

There were six thwarts in each of *Titanic*'s lifeboats, both main and emergency.[3] In order to keep the weight of persons down as low as possible in the boat, and yet not position them so low as to make it difficult to use the oars, the depth from the top of the gunwale to the upper surface of the thwarts was standardized. In the 25ft cutters, this distance was 10½in; in the 30ft boats, the distance was 11in.

As soon as the risings were secured and the keelson placed in position, the thwarts were cut to length, planed on both sides and attached to the risings. The thwarts were made of pitch pine and measured 9in x 1¾in in the 30ft boats and 8½in x 1¾in in the emergency cutters. Support was given to the thwarts in lifeboats fitted with buoyancy tanks by the tank cleading. Parts of the tank cleading – solid pieces of wood ¾in thick – were located immediately under the thwarts and permanently secured to the thwart and edge strip or bilge stringer. The thwarts, whose edges were rounded, were secured to the risings by at least two screws at each end.

The sternsheets were of greater length than the usual distance between the thwarts and as the stern seat was very wide to allow the gangboard to be fitted to take the lifting hook, one of the thwarts was fitted under the seat with the usual single knee. The gangboards forward and aft were fitted so that the upper surface was kept flush with the benches by recessing the gangboard over the thwart and securing the two together with three screw bolts.

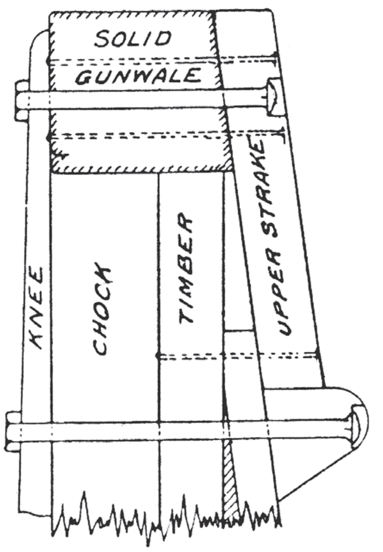


Fig. 23-13 **Gunwale** – One method of gunwale construction used during the period. This was similar to the configuration of *Titanic*'s boats. *(Ship's Boats/Authors' collection)*

Gunwales

The box form of gunwale was considered to be the strongest means of construction for all types of boats. The timbers were carried to the upper edge of the inner gunwale, or 'inwale', and sheer strake. Before timbering, a hardwood filling piece was fitted between the sheer strake and the timbers, fore and aft, tapering from the full thickness at the lower edge to half the thickness of the binding strake at the upper edge. By tapering this filling piece, the fairness of form was maintained in the boat.

The inwale was American Elm, about 3½in molded, and fitted in one piece from the stem apron to the sternpost apron. The upper strake (sheer strake) was 4½in x ¾in, also of American Elm. The breadth was arranged to suit the position of the rubber to enable the throat bolts connecting the thwart knees to be fitted well down towards the side benches. The inner gunwale and sheer strake were secured to every timber by copper nails, clenched over rooves and placed in reel fashion. Care was taken before fitting the combinations of a box gunwale to see that all faying surfaces and heads of timbers were well coated with white-lead paint. In addition, a reinforcing plank called a 'clamp' was installed along the inboard edge of the gunwale, this clamp measuring 2in x 2¼in and made of American Elm.

Solid chocks of hardwood were fitted between the timbers in way of the thwart knees, breast-hooks and crutches so that between the sheer strake and inwale, with the exception of these chocks and the capping piece, an open space was left which ventilated the gunwale. These chocks were select hardwood, free from sapwood and well-secured in position. The standard practice in most shipyards was to fit a capping-piece about 5/8in thick for the full length of the gunwale, well secured to the inner gunwale and sheer strake by brass screws. There were two common methods of ending the gunwales at the apron. The first method had the end of the gunwale cut off with a square butt and checked into the apron; the second method provided for the end of the gunwale to be cut at a bevel to suit the back of the apron.

Oarlocks in small open boats were originally cut out of the sheer strake to take the oar. When the boat was under sail, the oarlocks were filled in with portable poppets and attached to the boat with lanyards. However, a true oarlock was not often seen in boats for the mercantile service; the term 'oarlock' eventually came to be synonymous with 'crutch', which is a U-shaped metal fitting on a swivel, fitted in the gunwale to hold the oar. On *Titanic*'s boats, crutches were used only for

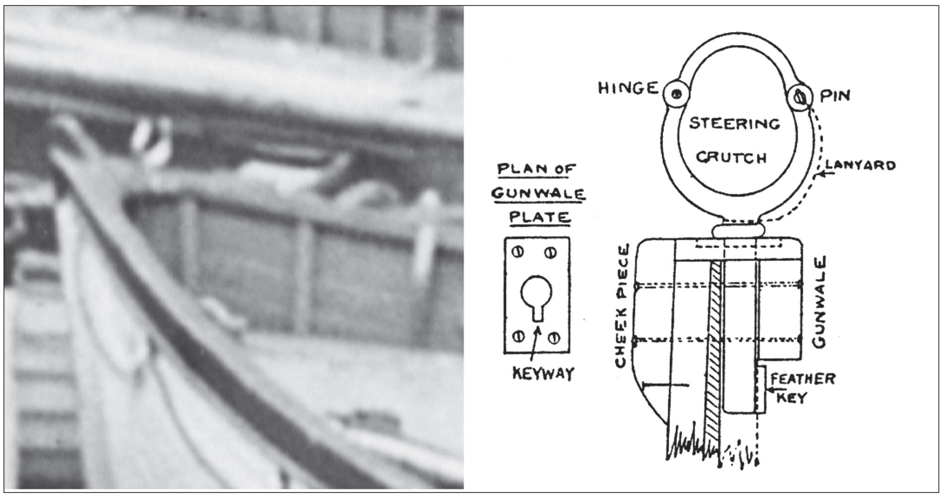


Fig. 23-14 **Steering Crutch** – At left, an enlargement of the stern of one of *Titanic*'s 30ft open boats, with the steering crutch in position. At right, an illustration showing how these were generally installed. *(Left image Josha Inglis collection; right image from Ship's Boats/Authors' collection)*

the steering oar at the stern, the rowing oars being fitted into thole pins instead.

In fitting the crutch for use with the steering oar – termed the 'steering crutch' – the depth of the gunwale was insufficient to adequately support the shank of the crutch. This made it necessary to fit toe cleats immediately below the gunwale. The crutch holes, after being drilled, were burnt out with a hot, round bar of iron which prevented the wood from swelling and allowed the crutch to be inserted without difficulty. The shank of the crutch was frequently keyed on one side, with a matching keyhole on the gunwale plate. When the crutch was inserted, turning it 'locked' it in place and prevented its inadvertent removal when working the oar. Each crutch was also secured by a chain lanyard to the boat.

Side benches

The side benches in an open lifeboat formed the cover for the buoyancy air tanks and became a permanent part of the structure. Side benches also provided additional longitudinal strength, and it was common to secure these lengths in one breadth. The material was pitch pine, 1⅜in thick. The side benches were fitted in continuous lengths above the thwarts and ran from bow sheet to stern sheet. The center portion, or gangboard, was made of the same material as the thwarts. A common practice was to slightly check the gangboard over the thwart at one end while securely connecting it at the other to a ledge chock attached to the apron; at about mid length, the gangboard was bolted to a crosspiece let into the rising. This provided a rigid connection for the fastenings of the lifting hooks, an important factor with a lifeboat filled with a crowd of passengers hanging 65ft in the air. Where double knees were fitted, as was the case with *Titanic*'s boats, the lower palm connecting bolts efficiently secured the side benches to the thwarts.

Foot spars

Foot spars, or 'stretchers', were placed in the most suitable positions for the efficient use of the oarsmen. The foot spars were made of stout pieces of American Elm, 2in square in section. They were removable, being fitted into cleats attached to the tank cleading by screws from the back.

Thwart knees

The 30ft boats were fitted with double thwart knees made of galvanized iron, except for those at the end thwarts which were single knees. The knees were substantial sections with at least 1¼in of material at the throat. The fastenings were arranged so as to obtain the greatest amount of security in cooperation with the combinations in way of the gunwale; nut and screw bolts were fitted for the purpose, the upright arm having one security through the center of the gunwale, timber, or chock, and upper strake, and another through the hardwood chock, binding strake, and rubbing strake, the nuts being on the upper arm of the iron knee with the bolts lightly clenched over the nuts. There were generally three fasteners in the horizontal arm attached to the side benches or thwarts, the center being a stout screw and the other two being ordinary nut-and-screw bolts. In this case, the nuts were placed on the underside of the thwart and screwed up on stout washers with the points of the bolts slightly clenched over the nuts. If the nuts were secured on the horizontal arm of the knee, they were a source of danger to men running along the side benches. It was usual to fit a protecting strip of wood, or listing, attached to the thwart to keep the buoyancy air-cases off the nuts. Solid hardwood chocks were fitted behind the knees and arranged to grip two timbers.

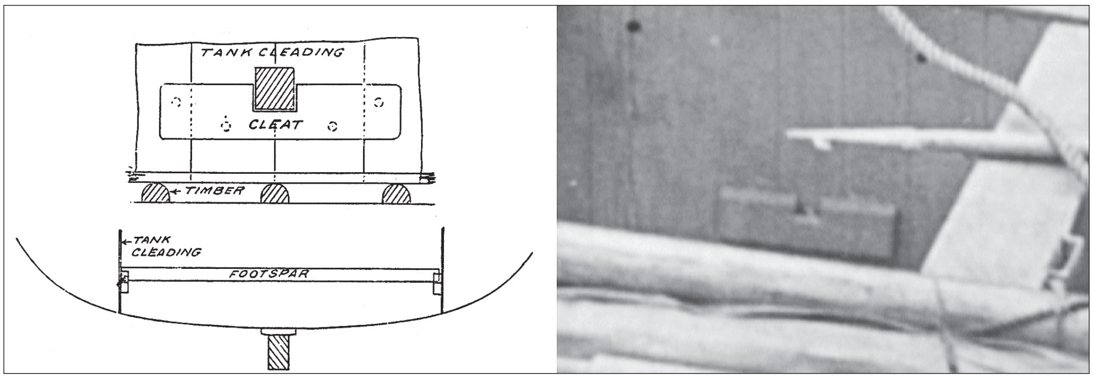


Fig. 23-15 **Foot Spar.** *(Left image from Ship's Boats/ Authors' collection); right image Josha Inglis collection*

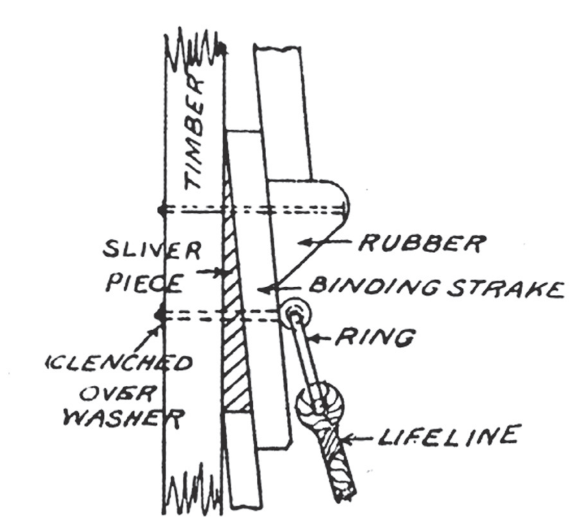


Fig. 23-16 **Rubbing Piece** – The rubbing piece, or 'rubber,' was fitted fore-and-aft at the widest point of the boat, and served to protect the boat from damage when coming alongside a wharf, the hull of the ship, or another boat. American Elm was typically used as elm is a tough, resilient, fibrous wood not prone to splitting or cracking. *(Ship's Boats/Authors' collection)*

Breasthooks

The combinations at the ends of the boats had to be strengthened to handle the heavy stress created by the lifting hooks. Stout breasthooks were fitted at the aprons and gunwale ends; the fastenings of which were similar to those of the thwart knees and having a throat bolt which passed through the face of the stem and sternpost.

Lifeboats over 24ft in length were fitted with an upper and a lower breasthook, both at the stem and sternpost. The breasthooks were iron and not less than 1¼in at the throat. When the lifeboats were lifted from the ends, as was the case with the Welin davits, a lower breasthook or deep floor was essential. The lower breasthook was fitted midway between the deadwood and apron scarf and the upper breasthook and was usually incorporated with the ending of the bilge stringer.

Rubbing plank

The rubbing planks, or 'rubbers', were made from 1½in x 1½in pitch pine, half-round or pear-shaped in cross-section, extended in one piece for the full length of the boat and secured to alternate timbers with copper nails clenched over rooves. The rubbers not only formed a protection to the gunwales, they were also excellent longitudinal stiffeners when attached in association with the fastenings securing the vertical arms of the thwart knees.

Tank cleading

The front casing which enclosed the buoyancy air-cases was worked in short gates between the thwarts and made up of narrow ¾in thick, 'vee'd' pine. Stout clamps were fitted to the portable portions of the casing to enable the tanks to be periodically inspected without damaging the cleading. Solid ¾in-thick supports were fitted under the thwarts and secured in place to substantially relieve the weight on the thwart. The cleading was held in position by an inner and an outer strip of wood running fore and aft at its lower edge. A portable securing strip, made of teak or other suitable hardwood and rounded at its upper edge, checked at the thwarts and butted at their

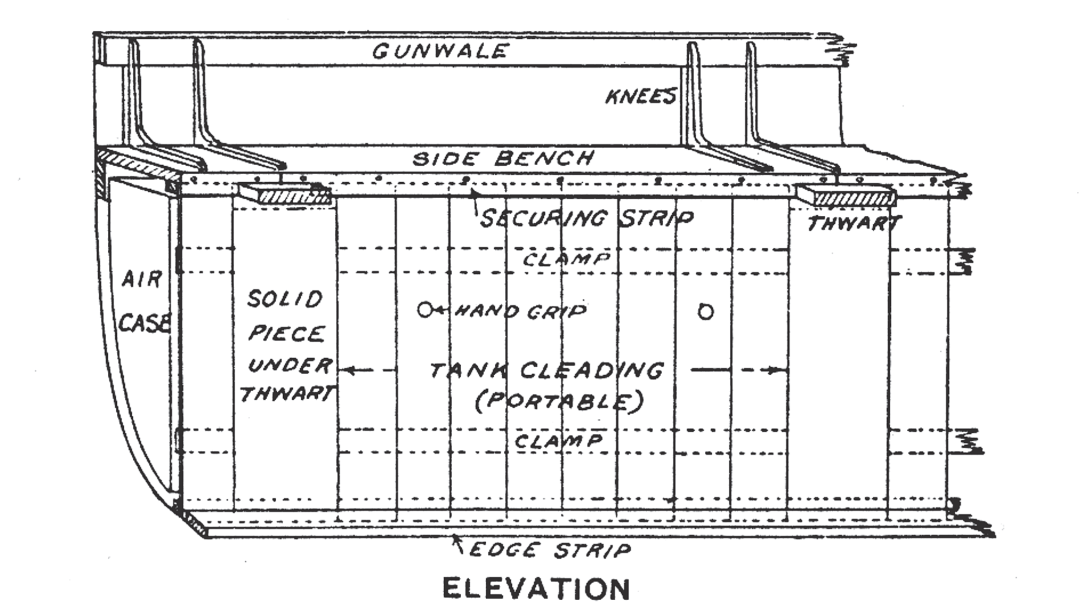


Fig. 23-17 **Method of Fitting Tank Cleading** – A drawing of a common cleading installation very similar to that used in *Titanic*'s 30ft boats. *(Ship's Boats/Authors' collection)*

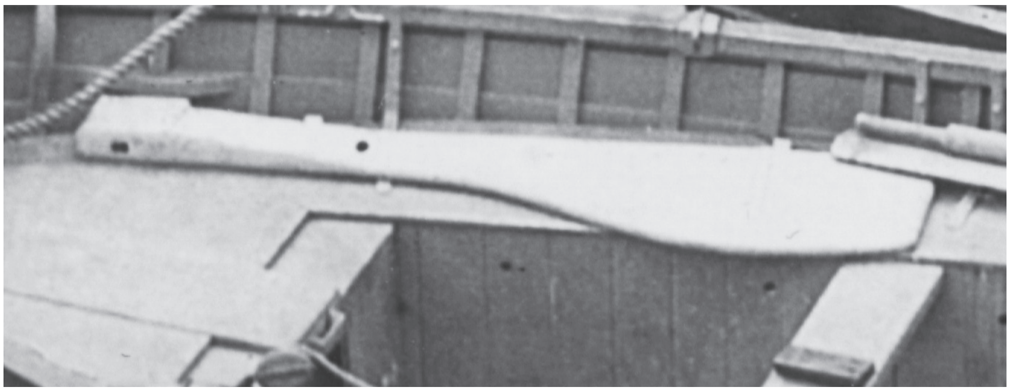


Fig. 23-18 **Lifeboat Rudder** – The rudder of one of *Titanic*'s lifeboats lying on a side seat. This close-up is from a photograph of a lifeboat tied up at New York after the sinking. *(Josha Inglis collection)*

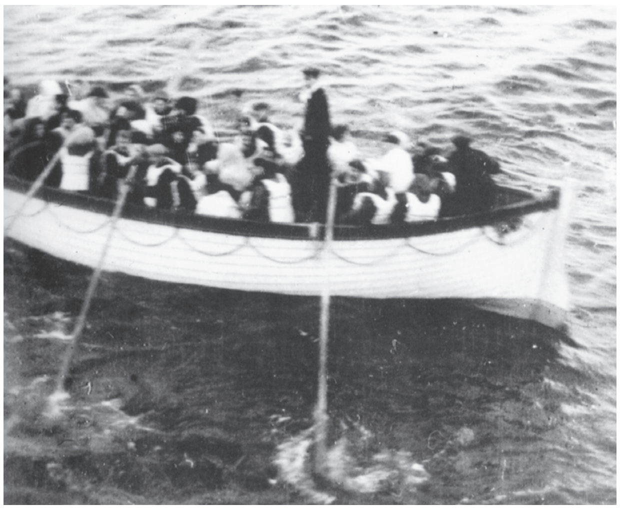


Fig. 23-19 **Rudder in Use** – One of *Titanic*'s lifeboats alongside *Carpathia*, with the rudder fitted. *(Private collection)*

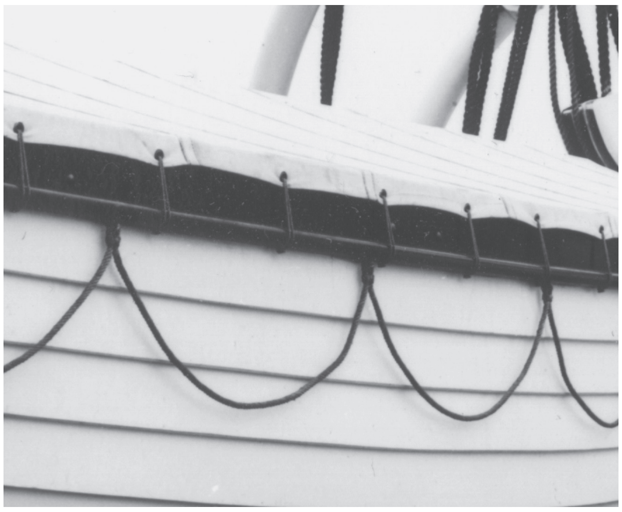


Fig. 23-20 **Grab Lines**.

centers, held the upper edge of the cleading securely in position. The cleading front was nearly flush with the side benches by the fitting of an inner upper ledge. The portable securing strip was attached to the side benches with button-headed brass screws. To provide for easy withdrawal between the solid supports under the thwarts, buoyancy air-cases were no more than 3ft to 6ft 6in in length. The method of fitting the cleading in the stern and head sheets, in its relation to the floorboards, enabled the former to be easily removed.

Rudder and steering arrangements

The rudder was 1¼in-thick elm as this type of wood was less prone to split. The rudder was worked in one piece, the lower edge being protected with a toe piece and secured by spikes. The upper portion was strengthened by cheek pieces of ¾in thickness, carried down below the upper pintle and worked with an oval section. The cheek pieces were well secured to the rudder by clenched copper fastenings. The arms to the lower pintle were fitted to within an inch of the full breadth of the rudder, which prevented the latter from splitting. The full width of the rudder carried down to the upper edge of the keel. The fastenings of the pintle arms to the rudder were heavy copper nails and well clenched. A guide bar was fitted on the sternpost to ship the rudder which was connected to the sternpost with support brackets at its lower and upper extremities. The head of the rudder was fitted with a tiller in addition to a yoke and lines.

Yoke lines were unsuitable for sailing a boat; the general practice was to fit a tiller. Both the rudder and tiller were secured to the boat by lanyards, eyebolts being fastened to the gangboard for this purpose. Heavy seas made control of a boat via a rudder difficult. Therefore, all boats carried a steering oar which was shipped through suitable crutches. A chock was fitted on each quarter, about 18in from the sternpost and bolted through the sheer strake and gunwale, through which was pierced the hole to take the crutch. The crutches were mounted at a height to clear the sternpost head and were portable, only being used when necessary.

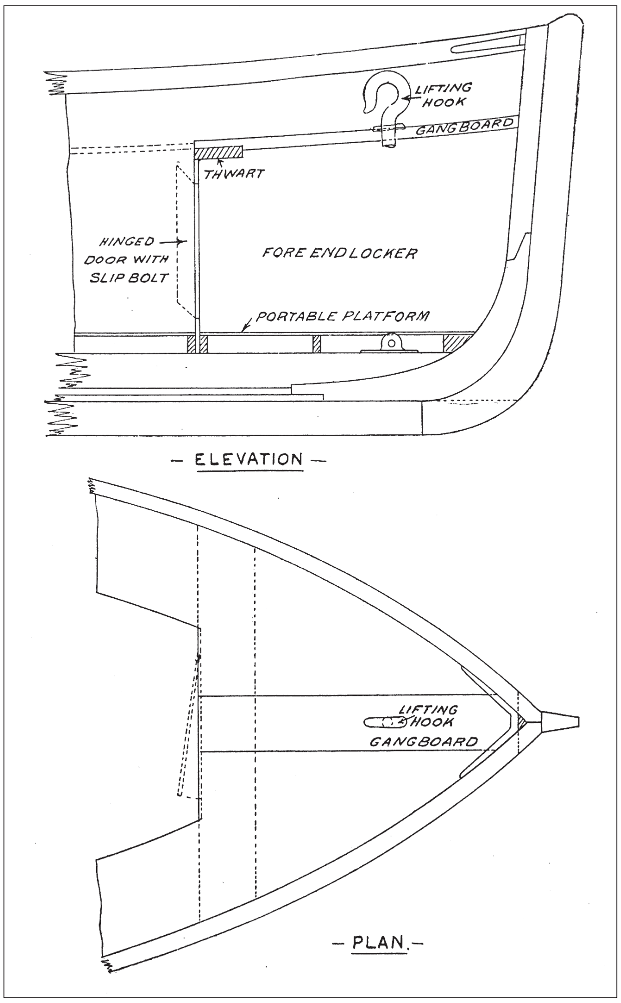

LIFTING HOOK
GANGBOARD
THWART
HINGED DOOR WITH SLIP BOLT
FORE END LOCKER
PORTABLE PLATFORM
— ELEVATION —
LIFTING HOOK
GANGBOARD
— PLAN.—

Fig. 23-21 **Gangboard and Locker**. *(Ship's Boats/Authors' collection)*

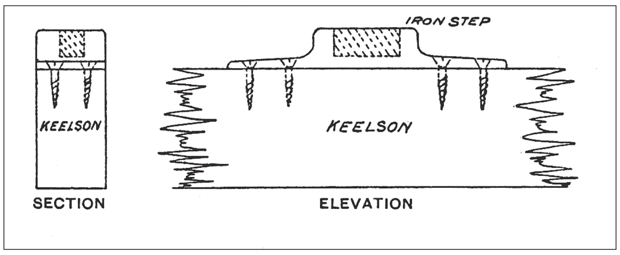

IRON STEP
KEELSON
KEELSON
SECTION
ELEVATION

Fig. 23-22 **Mast Step**. *(Ship's Boats/Authors' collection)*

Life lines

The life lines, or 'grab lines', were fastened to rings attached with nuts and screws. The nuts were hove up on washers, and the points of the screws were slightly clenched over the nut. These were secured through the planking and timbers just beneath the rubbing strakes and secured internally on the inside face of the timber. The life lines were becketed around the outside of the boat through the rings with full loops of sufficient length to reach within a short distance of the water line.

The quality of the lines was important and was usually of Italian hemp as this material was least affected by the weather.

Equipment lockers

All fully equipped lifeboats were fitted with at least one locker to store equipment and protect it from the weather, and to provide the maximum space in the boat for seating passengers. The usual practice was to fit a locker at each end of the boat.

Portable bottom boards were placed in the end lockers above the keelson to keep their contents raised up above any moisture that might have collected on the locker's floor. Hinged doors were fitted with slip bolts to enclose the provisions, as portable doors could be lost overboard.

Mast step

To secure the mast step, the thwart taking the mast was increased in width and the arms of the hasp were well secured to the thwart by bolts. The step was fitted on top of the keelson (which was not cut to receive the heel of the mast), to which it was secured with heavy screws and supported with cheek pieces covering the full depth of keelson and thickness of step, the combination being secured with nuts and screw bolts. The securing bolts through the keelson and keel supported the step and

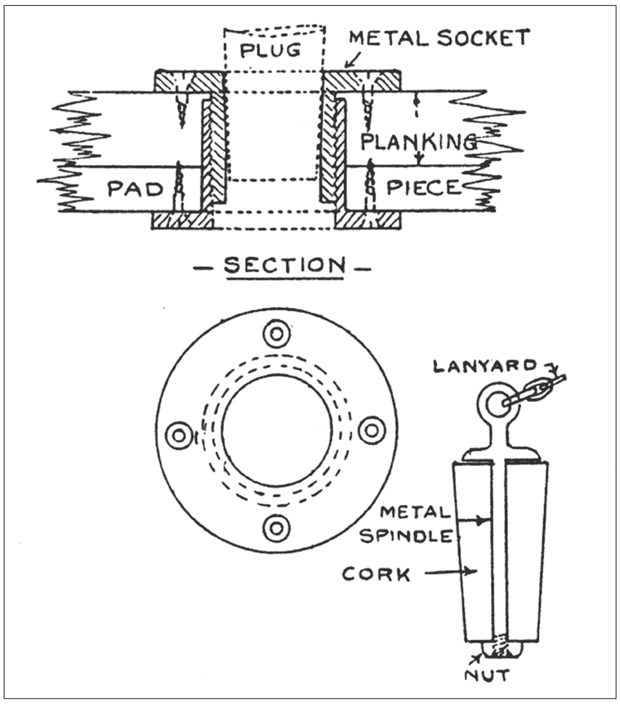

PLUG
METAL SOCKET
PLANKING
PAD
PIECE
— SECTION —
LANYARD
METAL SPINDLE
CORK
NUT

Fig. 23-23 **Drain Plug Details**. *(Ship's Boats/Authors' collection)*

made the connections as rigid as possible. The step and cheek pieces were either English Elm or iron.

Plugs

Each lifeboat was fitted with two drain plugs for each plughole. The position was supposed to be one of easy access, and the bottom boards were arranged accordingly. The common practice was to fit a cork or soft pine plug into a brass socket, and to secure a pad piece on the outside surface of the planking in way of the plughole, particularly when soft pine plugs were used.

The plugs corresponding with the collapsibles, unlike the open lifeboats, were always in place. They were only removed for servicing. The Engelhardt boats had two bottoms that were practically air-tight in the space between them. A pipe connected the two bottoms, passing through them as the drain. These boats were considered to be self-emptying; their design allowed them to stay afloat even with a plug missing. On the night of *Titanic*'s sinking, the crewmen who attempted to find the plugs, in the usual sense of an open boat, could not because the plugs were already in place.

Bottom boards, stern and head sheets

To protect the timbers and fastenings of plank landings, portable bottom boards were fitted. The bottom boards would take a good deal of rough usage and were made from fairly tough material such as teak, elm, or larch not less than $^5/_8$in thick and well-secured together. The stern and head sheets were the platforms situated forward and aft at the ends of the boat, and were usually portable.

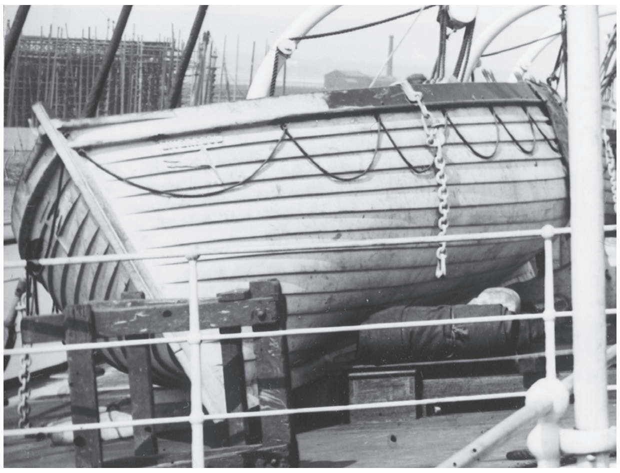


Fig. 23-24 ***Oceanic* Lifeboat Being Painted** – One of *Oceanic*'s lifeboats being fitted aboard the ship. The white construction paint on the sheer plank is being painted the customary brown. *(H&W/Authors' collection)*

Paint

Faying surfaces of all material were painted as progress was made on the construction of wooden boats. Some ship owners demanded that the boat be covered with two good soaking coats of boiled linseed oil and allowed to dry before the paint was applied. The inclusion of such a clause in a specification not only extended the life of a boat, but also increased the resisting qualities of the planking to the effects of the weather and changes of atmosphere.

As each particular detail of the combination in the frame was worked, the faying surfaces were thickly covered with good white-lead paint, particularly in way of the hog piece, keel, deadwoods, apron, and stem or sternpost. The landing edges of the planks in the clinker-built boats and the various details of the box gunwale and capping piece were also painted before they were secured in position. The most important protective covering the boat received was that which was applied to the inside of the planking before the timbers were worked. Board of Trade specifications called for three coats of quality white-lead paint to be applied on the outside and two coats on the inside. The second coat of paint was applied to the planking and timbers before the buoyancy air-cases were inserted and the tank cleading secured in position. Where boats were subjected to alternating conditions of heat and cold, it was required that the wood be thoroughly seasoned. Immediately after the stem and sternpost were erected, they were coated with an oil varnish as protection from the weather and to prevent the oak from opening out during the period of construction. It was common to varnish the outside of the upper strakes, the rubbers, and the gunwales with two coats of good oil varnish. Every portion of the boat was painted, particularly those portions which were not exposed to view such as the underside of thwarts and side benches.

Externally, *Titanic*'s lifeboats were painted white; the sheer strake, capping piece and gunwales were painted brown as was common with White Star Line lifeboats. The interiors of the boats were painted with a third and final coat of a color called stone; this was a tan hue, applied after the boats were fitted on the ship.

Lifting hooks

Lifting hooks in a lifeboat were selected to meet the ordinary conditions of lowering a boat over the side of a vessel into the water with a disciplined crew. They were usually wrought iron or steel, and designed to be strong enough to carry the weight of the boat fully loaded with all standard equipment, and with the maximum number of persons aboard the boat, having in reserve a safety factor of four people. However, as demonstrated on *Titanic*, during an emergency, launching the boats was, in many cases, undertaken with the help of untrained passengers and crew, and stresses were exerted that could not have been anticipated.

The distance between the lifting hook and the stem or sternpost head depended on the type of davit fitted to the vessel. Special precautions were taken with lifeboats lifted at the extreme ends, as in the case of the Welin Quadrant davits. The fastenings of the deadwoods, keelson and keel were carefully considered in their relation to the fastenings of the keel plates, and were arranged so that the fastenings to the frame combinations of the boat would serve the double purpose of also securing the keel plates of the lifting hooks.

When fitting the keel plate, the lugs were made of sufficient length to allow the insertion of the pin to take the heel of the lifting bolt as there was little room to spare between the planks at the extreme ends. The securing bolts were arranged square to the keel plate to avoid the necessity for tapered washers under the nuts. The heads of the bolts were square or oblong to suit the bearding of the stem, which prevented them turning. Before the keel plates were made, the builder made an inside mold to the curvature of the deadwood and keelson, and from this he made another mold which the smith could apply to the keel plate during the operation of forging.

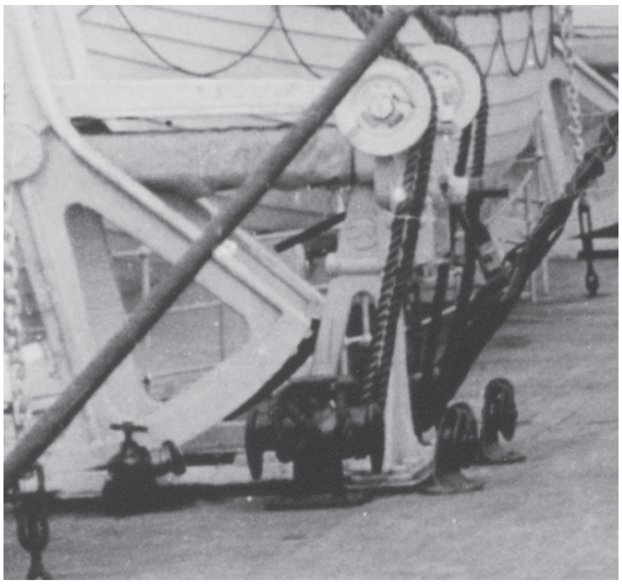


Fig. 23-25 **Deck Gear** – This image shows the deck gear for one of *Titanic*'s davits. At lower right are two snatch blocks mounted to the deck for the use of electric winches with the davits. While these boats could be lowered by hand, they could not be raised without the use of the winches. Below the davit pulley, under the coiled falls, is one of the T-shaped bitts that assisted crewmen in lowering the boats. By taking a turn around the bitt, the load was reduced to manageable levels for the crewmen handling the falls. The object protruding from the deck to the left of the bitt is a deck hydrant.

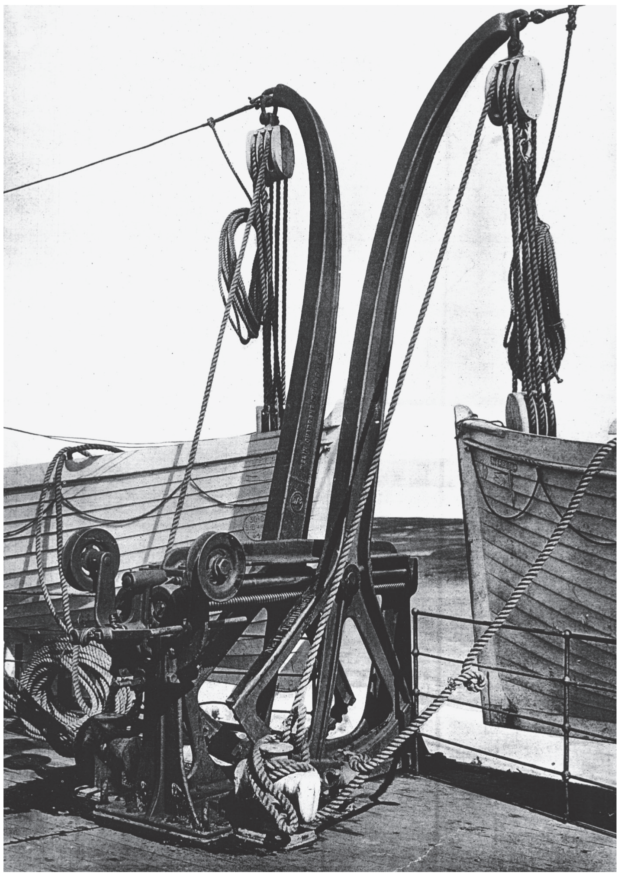


Fig. 23-26 **Lifeboat Falls** – This image shows in great detail the blocks and falls for two of *Olympic*'s lifeboats. The lines which hang from the span between the davit arms are 'lifelines' and are intended for use by the deckhands to descend to the boat after it has been lowered. Here, the lifelines have been coiled and lashed to the falls. The railing seen here, still unpainted, is a portable guard rail.

Lowering gear

The most important factor for ensuring the rapid and trouble-free launch of a lifeboat was the efficiency of the lifting and lowering gear. To facilitate this, there was a bitt and sheave at the heel of each davit. In each case, the falls could be taken across the deck; this allowed a number of men to speedily lift and easily control the boat and davits.

Where more than one boat was served by one set of davits, it was essential that provision be made to prevent the lower blocks from 'toppling' and the falls from becoming twisted; if this occurred, it would hinder and greatly delay the process of lowering the second boat. After *Titanic*'s sinking, many companies (including the Welin Davit Company) would patent special 'non-

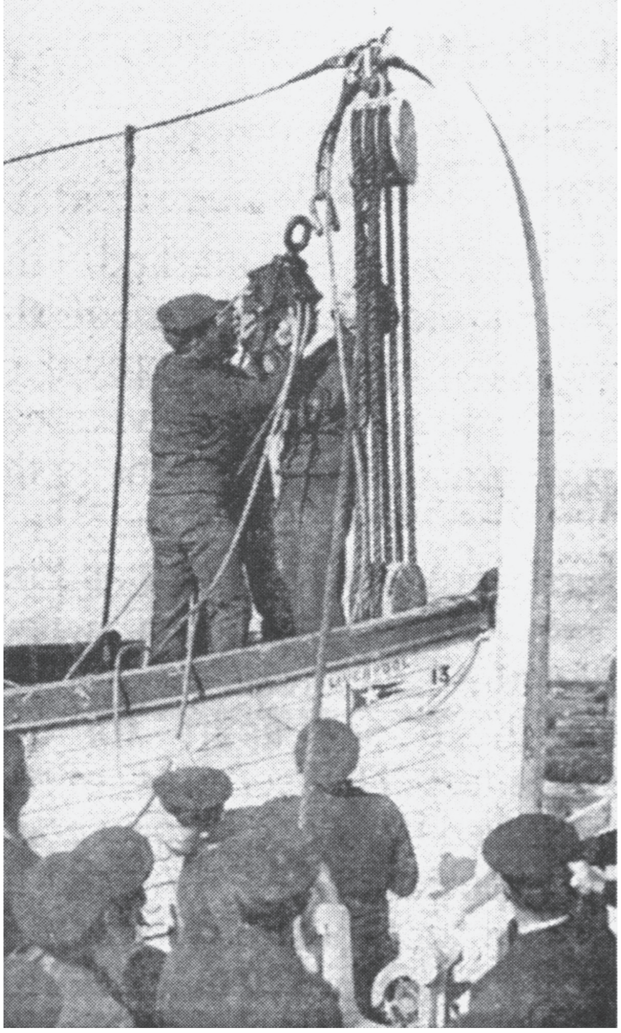


Fig. 23-27 ***Olympic*'s Lifeboat Blocks after Refit** – After *Titanic*'s loss, *Olympic*'s blocks were switched out for a design that was apparently less prone to toppling. *(Authors collection)*

toppling' blocks. Unfortunately, it appears that *Titanic* was fitted with regular treble blocks whose only real protection against toppling was the weight of the devices themselves.

The design and action of the Welin davits will be discussed in greater detail in a later section.

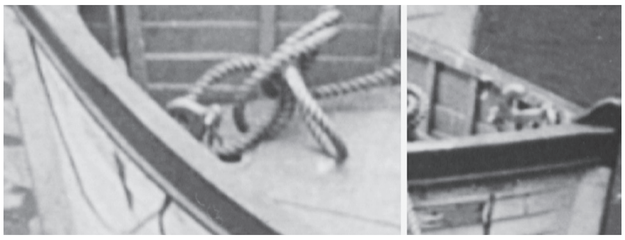


Fig. 23-28 **Murray's Releasing Gear** – Enlargements of the releasing gear in *Titanic*'s lifeboats shows the patent hook which has been disengaged. A hole in the gangboard can be seen where the wire passed from below. The idea behind releasing gear is that a wire was installed between the hooks and was run behind the cleading or other interior fittings in order to keep it clear of the general working of the boat. Upon pulling on the wire, both hooks were to release at the same time allowing for an even disconnect from the falls. *(Both images Josha Inglis collection)*

Disengaging gear

The process of releasing a ship's boats from the overhanging falls attached to the davit blocks and into the water was crucial to the safety of the passengers. When release was actuated by hand, the process would be both difficult and dangerous if the two hooks were not released simultaneously. If the boat was lowered in a heavy sea, there was also the danger that the forward block would drop below the lifting hook and come free with the after hook still engaged, thereby imperiling the boat and its occupants, unless an arrangement of mousing the hook was fitted which would prevent the link on the block from freeing itself.

The mechanism by which the disengaging gear operated varied according to the manufacture. Where members of the crew were not constantly attached to one ship, these differences in the operating movement of the various gears created confusion at the worst moments. There were also differences of opinion as to how to simultaneously release lifting hooks from the falls. It must be remembered that the question of seamanship in controlling the boat and preventing her from being

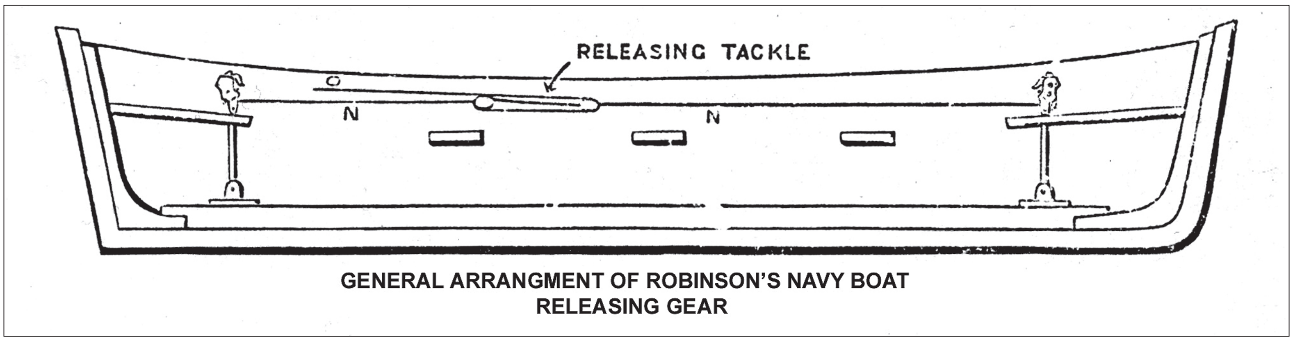


Fig. 32 **Robinson's Releasing Gear** – Robinson's Navy Boat Releasing Gear was one of the numerous types of releasing gear introduced in the wake of the *Titanic* disaster. This is shown only to demonstrate the concept of releasing gear in general. Murray's Releasing Gear was similar in design and worked on the same principle.

drawn under the stern of the vessel, therefore coming into contact with the propellers, had to be considered as well. Because of this it was of paramount importance that a boat being lowered into the water should be cleared from the falls as quickly as possible.

By 1912, the Board of Trade had not yet laid out specific requirements for engaging/disengaging lifeboat gear. However, it was imperative that the gear be arranged to ensure simultaneous release at both ends of the boat. It was intended that the hook offer no resistance to release should there be a towing strain on the falls, and that it be capable of being unhooked manually. The Murray's Disengaging Gear[4] utilized a lever within the center of the boat that actuated the disengaging mechanism simultaneously at both ends. This was accomplished with chains that ran the length of the boat fore and aft, fastened to the inside of the boat in a safe place so as to not interfere with the passengers. The chains were led

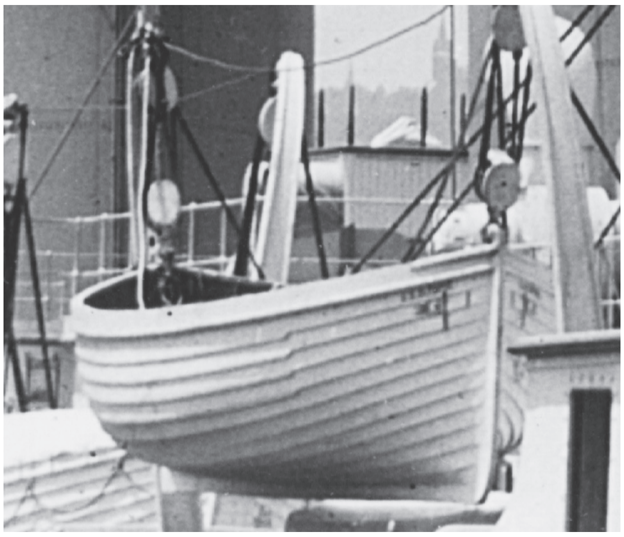


Fig. 23-29 **Emergency Cutter No.1, *Olympic*** – On *Olympic*, the sheer planks on all boats were initially painted white, as seen here in this image from her maiden voyage. The planks would eventually be painted brown as were *Titanic*'s from the beginning. *(Josha Inglis collection)*

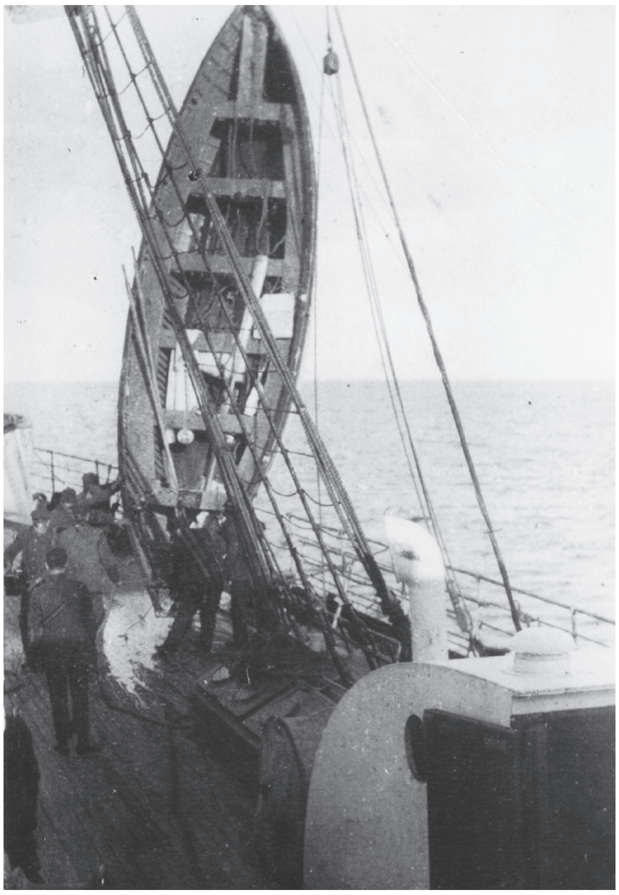


Fig. 23-30 **Cutter Being Loaded Aboard Carpathia** – In this image, *Titanic*'s port side Emergency Cutter No.2 is being loaded aboard *Carpathia*. This photo shows a large amount of detail. The bottom boards are visible as well as oars, and on the right side of the boat on a side seat is a fender, used to cushion the side of the boat when coming alongside the ship, another boat or the dock. (These are somewhat elusive as there is little mention of them in period books. However, one of these did survive from a lifeboat and is held in a private collection.) There are two canisters seen dangling by a rope over a thwart; these appear to be 'Holmes Lights' that were attached to lifebuoys when on the ship. There must have been some trouble with hoisting this boat because the after gangboard has been torn off as is evidenced by the darkened patch on the after thwart at the bottom. A pool of liquid is on the deck, and nearby a deck hand is carrying what appears to be one of the lifeboat lamps; the spill on the deck may have come from this lamp. *(National Archives/Authors' collection)*

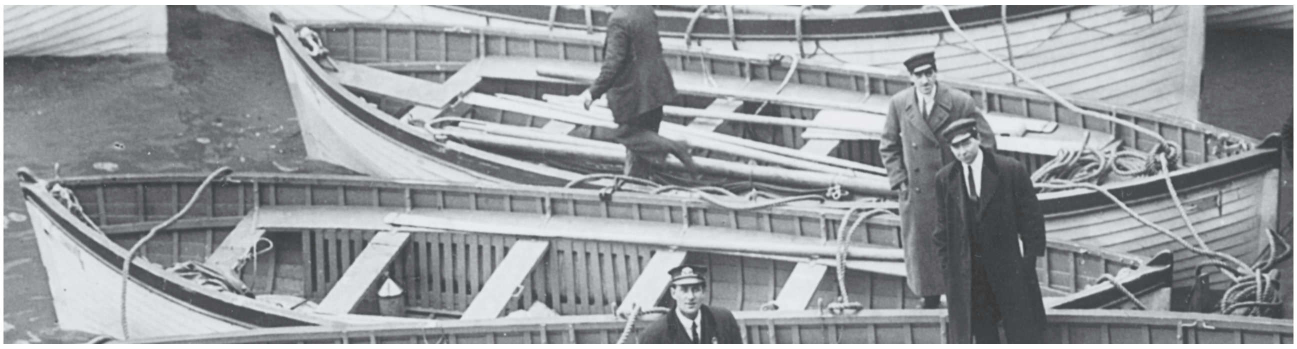


Fig. 23-31 **Interior of Emergency Cutter** – *Titanic*'s Emergency Cutter No.1 (top) and No.2 (bottom), shown at New York after *Titanic*'s sinking. Length aside, these cutters lack some of the characteristics of the 30ft boats, notably the solid cleading and the stern and head sheets. *(Josha Inglis collection)*

by fairleads to prevent jamming and nipping and were attached to permanent parts of the inner fittings.

The disengaging gear installed in the open lifeboats was designed to be actuated before the boat was waterborne; few designs proved to work efficiently. The emergency cutters were required to have disengaging gear that enabled the boats to be lowered while the ship was under way. These devices allowed the lifting hooks to disengage while the boat was still in the air, just above the water. *Titanic*'s emergency cutters were also fitted with Murray's Disengaging Gear.

25ft Emergency Cutters

The details of construction for the 25ft cutters were much the same as the 30ft open lifeboats, with a few noteworthy exceptions. These boats were not fitted with head and stern sheets. Their tank cleading pieces were not fastened flush with each other, but were spaced apart at intervals. The gangboards were fitted above the fore and aft thwarts, connecting to the aprons. The side seats were fastened with single galvanized iron knees, not the double configuration employed on their larger counterparts. There were also no storage lockers.

Engelhardt Collapsibles

The Engelhardt collapsibles were a patented design developed by a Danish Captain V. Engelhardt; the four used on *Titanic* were supplied by McAlister & Son of Glasgow. These lifeboats were similar to a wooden raft with canvas sides that were raised when the boat was needed. The lower part was designed to float even if the boat sprung a leak. It consisted of a keel, a mid-keel, two side keels and two double side planks. At the side planks, on both sides of the floating body, were connected strips of wood where the fenders were fastened. The fenders were built up by short sacks filled with Kapok, a buoyant filling made of vegetable fiber. Between the mid-keel, the side keels and the outer planking were more sacks filled with Kapok; the bow and stern sections of the floating body were filled with cork. The upper part of the boat had a railing to which a dollboard was fixed.

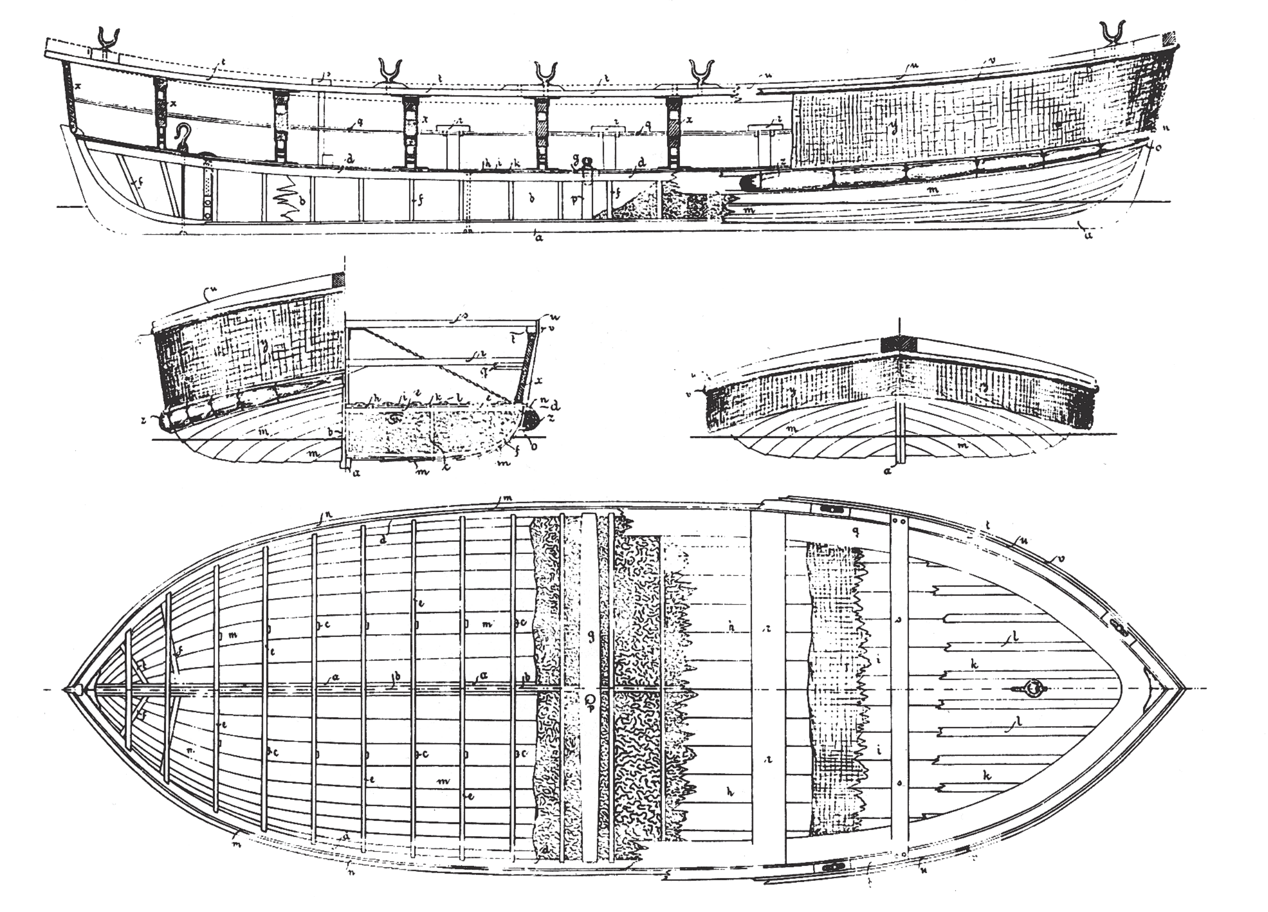


Fig. 23-32 **Engelhardt Collapsible Lifeboat** – Drawing of an Engelhardt collapsible lifeboat of the type used on *Titanic*. *(Robert Hahn collection)*

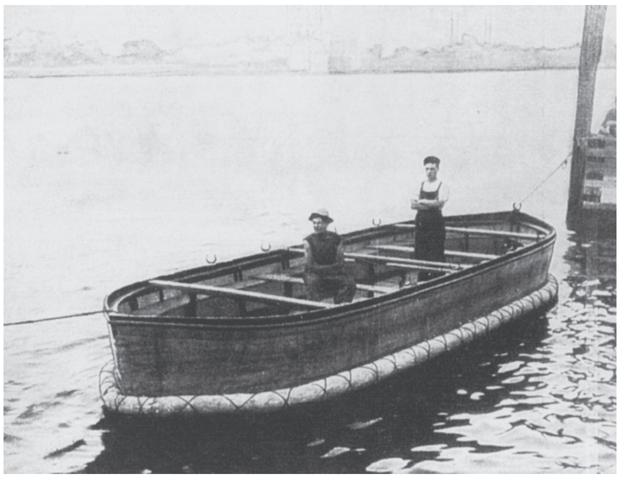


Fig. 23-33 **Engelhardt Collapsible with Sides Raised** – An Engelhardt promotional photograph showing a collapsible boat with its canvas sides raised. *(Robert Hahn collection)*

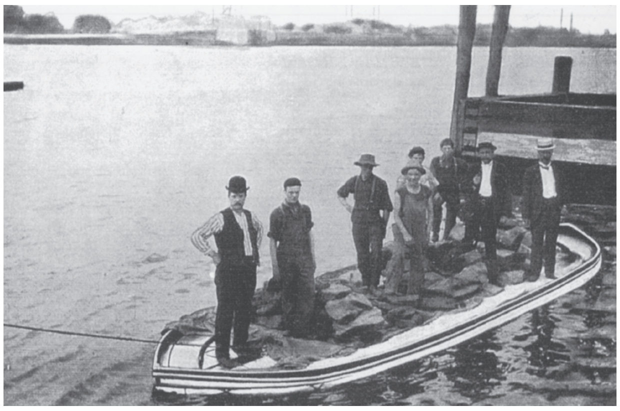


Fig. 23-34 **Engelhardt Collapsible with Sides Down** – In another Engelhardt promotional photograph, a collapsible boat demonstrates its ability to remain afloat even with the sides down. *(Robert Hahn collection)*

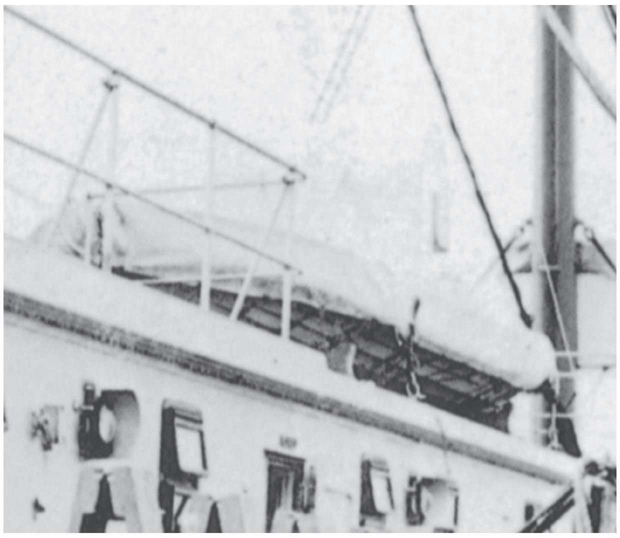


Fig. 23-35 **Collapsible Lifeboat Stowed on *Olympic*** – A collapsible lifeboat stowed on *Olympic*'s Officers' Quarters deckhouse roof, photographed immediately after *Titanic*'s loss. *(Father Browne photograph/Authors' collection)*

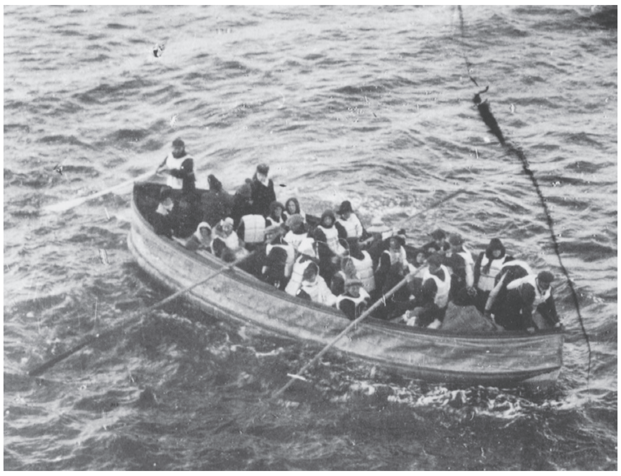


Fig. 23-36 **Collapsible Lifeboat in Water** – *Titanic*'s Collapsible D approaching the *Carpathia*. What appears to be an oar used as a rudder is just that; this was the 'steering oar' and it is being used for its intended purpose. The steering oar was 2ft longer than the other oars. *(National Archives/Authors' collection)*

Four hinges connected the upper frame with the floating body. The upper cross connection was two cross-parts which connected to the railing. Below these cross-parts were two collapsible supports per side. Running all around was a one-piece seat plank and connected to the seat planks were cross planks or thwarts.

To make the boats ready, two men lifted up the cross-parts. This action caused the seat planks to slide down until they rested on the hinges, which were then fixed by the seat planks. Then four collapsible supports were pressed into tracks.

The Engelhardts that were stowed under the two forward-most lifeboats were utilized without any problems during the disaster. However, it appears that not enough time was spent drilling the crew in the deployment of the two Engelhardts on the roof of the Officers' Quarters deckhouse which was some 8ft 3in above the level of the Boat Deck. During the disaster, the specified procedure for launching these two boats was not followed. These collapsibles were provided with portable blocks and tackle that were to be placed within rings fitted to the inner two shrouds of the No. 1 Funnel. With these in use, the process of lowering these boats to the Boat Deck would have been accomplished without difficulty. By the time the officers decided to lower the collapsibles from the roof of the deckhouse, the tackle needed was already under water as it was stowed in the Bosun's Store in the bows of the ship. Instead, they attempted to slide one of these boats – Collapsible B – from the roof to the deck below utilizing the lifeboat ridge spars, which were about 30ft long. As the Engelhardt collapsible weighed approximately 33cwt, it ultimately snapped the ridge spars in half causing the boat to fall to the deck.

MEASUREMENTS AND CAPACITIES

Dimensions and cubic capacities

If one reads the contemporary and modern references to *Titanic*'s lifeboats, one will be struck by the inconsistency of the measurements that are given. This confusion relates to the difference between methods of calculation for cubic capacity numbers and the occupancy that was finally approved by the Board of Trade inspector.

The figures shown in Table II below reflect the size and capacity of *Titanic*'s boats as presented in the final report of the British Wreck Commissioner's Inquiry; these are given in feet and decimals of a foot, not inches.

Table II – Lifeboat Dimensions and Capacities as Determined by Stirling's Rule

Type of Lifeboat	Length	Breadth	Depth	Cubic Capacity	No.persons
14 main boats	30.0ft	9.1ft	4.0ft	655.2 cubic ft	65 persons each[5]
25ft cutter	25.2ft	7.1ft	3.0ft	322.1 cubic ft	40 persons each
25ft cutter	25.2ft	7.2ft	3.0ft	326.2 cubic ft	40 persons each
4 Engelhardts	27.5ft	8.0ft	3.0ft	376.6 cubic ft	47 persons each

These dimensions, the differences between them and the methods by which they were calculated will be discussed in greater detail in the section that follows.

Length could be measured in several different ways. The 'extreme length' of a boat was taken from the forward side of the stem head to the after side of the sternpost head. This would have been the 'overall length' and had no bearing on the capacity measurements for the Board of Trade regulations. The numbers indicated in Table II were the dimensions to the outside of planks, or the 'external capacity'. The 'internal capacity length' was taken from the inside of the planking at the stem to the corresponding point at the sternpost. This length was only used when Stirling's Rule was employed for ascertaining the internal cubic capacity of a boat.

The 'breadth' of a boat was normally taken from outside the planking at the point where the width of the boat was the greatest. This dimension was usually measured from the outside of the upper strakes. However, the breadth used with Stirling's Rule was taken from the inside of the planking.

The recognized depth was the distance measured amidships, between the inside of the surface of the planking at the keel, to the level of the gunwale.

The time-consuming Stirling's Rule was generally used to initially determine the cubic capacity of a boat. This was very close to the method of measuring a ship's tonnage, but in this case the formula was used to determine the volume of the buoyancy air-cases based in turn on the capacity of the boat. The volume of the air-cases were not calculated upon the number of persons carried, but upon the cubic capacity. The formula by Stirling's Rule required dividing the boat into four sections and calculating them in such a way as to compensate for the curve of the sheer and depth; for all Section A boats, the total volume of the air-cases were not to be less than one-tenth of the cubic capacity. There were certain limitations to the depth used for calculating the capacity of an open boat in Section A. Lifeboat designs differed by builder and because of this supplemental rules were drawn up to compensate for boats with a deep mid-section. These rules were put in place because some ship companies prior to the enactment of this provision would try and cheat by providing boats that were unusually deep, but of average beam compared to their length. This design of boat would not interfere with open promenade space. These boats would calculate to the required internal capacity, but would be unsafe in actual use.

The limitations referred to were as follows:

(a) If the depth of the boat amidships exceeded 45 per cent of the breadth, the depth employed in calculating the area of the midship cross-section was deemed to be equal to 45 per cent of the breadth; and the depth employed in calculating the quarter-length sections was obtained by increasing this last figure by an amount equal to 1 per cent of the length of the boat, provided that in no case the depths employed in the calculation exceeded the actual depths at these points.

(b) If the depth of the boat was greater than 4ft, the number of persons given by the application of this rule was reduced in proportion to the ratio of 4ft to the actual depth until the boat had been satisfactorily tested afloat with that number of persons on board, all wearing life jackets.

In the case of the dimensions given for the fourteen open lifeboats in Table II, the limitations for depth qualify. The 30ft boats were, in fact, deeper than 45 per cent of the breadth, and the calculated depth defaulted

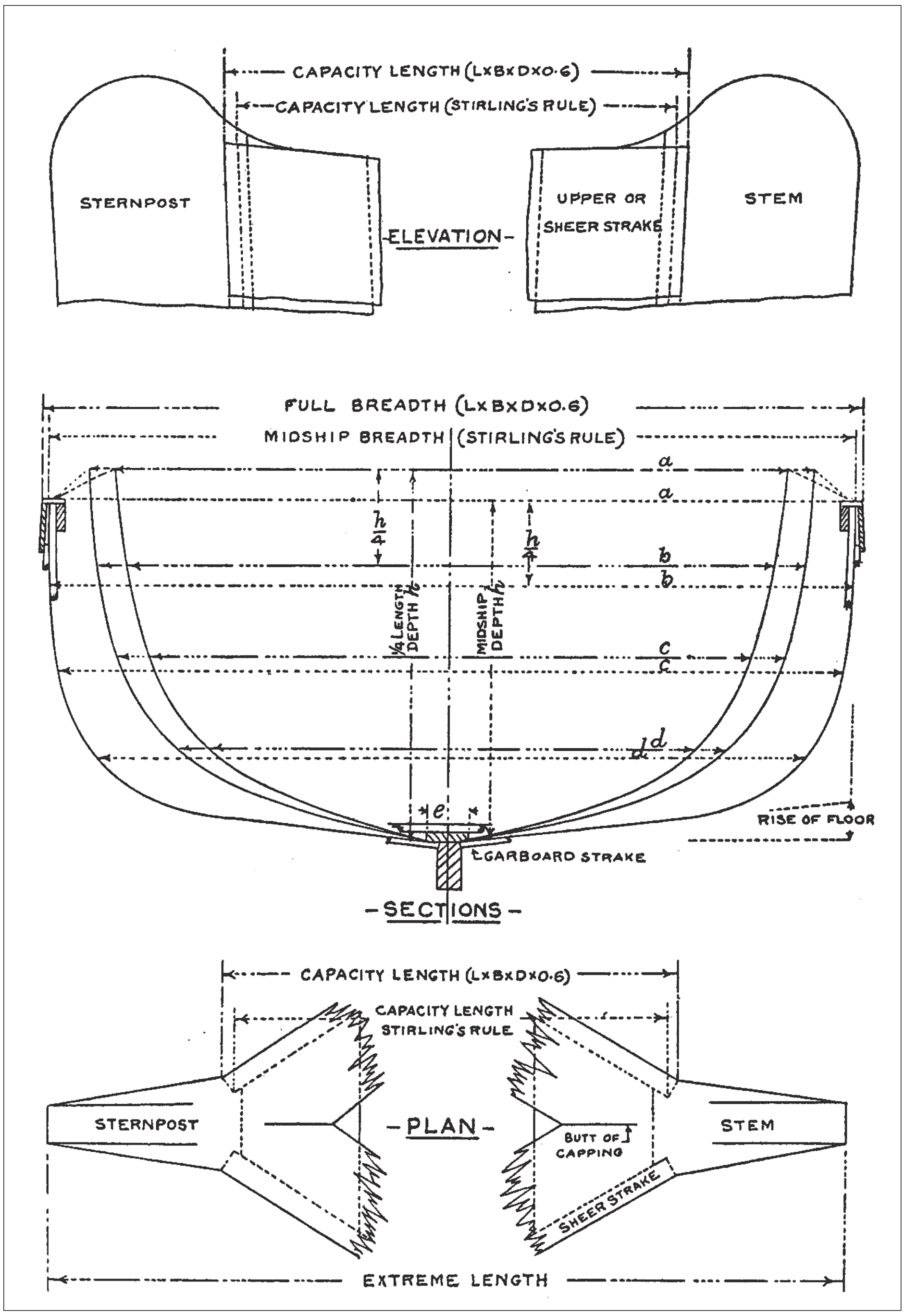

CAPACITY LENGTH (L×B×D×0·6)
CAPACITY LENGTH (STIRLING'S RULE)
STERNPOST
ELEVATION
UPPER OR SHEER STRAKE
STEM
FULL BREADTH (L×B×D×0.6)
MIDSHIP BREADTH (STIRLING'S RULE)
a
a
h/4
h/4
b
b
½ LENGTH DEPTH h
MIDSHIP DEPTH h
c
c
d
d
e
RISE OF FLOOR
℄ GARBOARD STRAKE
SECTIONS
CAPACITY LENGTH (L×B×D×0·6)
CAPACITY LENGTH STIRLING'S RULE
STERNPOST
PLAN
BUTT OF CAPPING
STEM
SHEER STRAKE
EXTREME LENGTH

Fig. 23-37 **Measuring Boats.** *(Ship's Boats/Authors' collection)*

to 4ft. Because these measurements were taken from the inside of the planking and were principally used to determine the volume of the copper air-cases according to Stirling's Rule, the length was 30ft and the breadth was 9ft. This formula gave the capacity of 648 cubic ft for each Section A boat.

The two emergency cutters fell under Section D of the regulations and did not require copper air-cases, although *Olympic*'s specifications and pictures of *Titanic*'s cutters indicate they were fitted anyway. Because the dimensions given in Table II are the external dimensions taken outside of the planks, the cubic capacity was greater than what would be finally registered by the Board of Trade.

The passenger capacity numbers listed previously in Table I correspond with *Titanic*'s 'Report of Survey for an Emigrant Ship'. This paper states that the fourteen 'Section A' boats had a total cubic capacity of 9,172.8ft and a combined capacity of 910 persons. The two cutters of Section D had a total capacity of 648.7 cubic ft and a combined capacity of 80 persons; and the four Engelhardts of Section E, a combined capacity of 188 persons.

The formula used in Table II is a bit different than that used for Stirling's Rule. The calculations for determining internal cubic capacity using Stirling's Rule required a great deal of effort for the boat builder. Since boat shops employed many builders and many of the boats, even from one shop, did not end up with identical dimensions, an option was introduced. The regulations allowed for a general rule to be used, provided it did not give a greater capacity than that obtained by the Stirling method. In the simplified rule, builders were allowed to measure the length and breadth 'outside' the planking and the depth 'inside' at the top of the bottom plank next to the keel. The depth used in calculating was not to exceed in any case 45 per cent of the breadth. The product of these dimensions multiplied by 0.6 resulting in the nearest whole number was deemed the capacity in cubic feet. It should be noted, however, that in all cases, the owner of the vessel had the right to require that the cubic capacity of the boat be determined by exact measurement.

The rules specified that boats of Section D and Section E were to allow 8 cubic ft of boat capacity for each statute adult (an adult being considered over twelve years of age; two children under the age of twelve could be carried in place of one adult). For example, the carrying capacity of one of *Titanic*'s cutters (25.2ft in length, 7.1ft in breadth and 3ft in depth) was determined as follows:

$$\frac{25.2 \text{ x } 7.1 \text{ x } 3 \text{ x } 0.6}{8} = \frac{322.1}{8} = 40 \text{ persons}$$

The passenger occupancy for 'Section A' lifeboats was calculated by taking the cubic feet, multiplying it by 0.6 and dividing it by 10. For *Titanic*'s main lifeboats, the formula using Simpson's Rule[6] for measurements was as follows:

$$\frac{30 \text{ x } 9 \text{ x } 4 \text{ x } 0.6}{10} = \frac{648}{10} = 64.8 \text{ persons}$$

After the *Titanic* disaster, the regulations became clearer on calculating the capacity of boats such as the Engelhardts. Because these boats had buoyant double bottoms, they did not fit into the standard formula. Lifeboat regulations enacted after *Titanic*'s sinking specified that the cubic capacity of the Engelhardt collapsible boats was determined by measuring in feet and fractions of a foot the length and breadth outside the canvas extension and the depth inside at the place of minimum depth taken from the inside of the bottom planking of the bottom to the top of the gunwale when extended. The product of these dimensions multiplied by a pre-determined fraction was deemed the capacity in cubic feet. To ascertain the carrying capacity, the product then had to be divided by 8.

The cubic capacity for the fourteen boats and two cutters, whether determined by Stirling's Rule or by the general method listed above, was used to determine the volume of the buoyancy air-cases and did not necessarily provide the final occupancy number of the lifeboats. After the boats were tested by being filled with men wearing regulation life jackets, the Board of Trade inspector would determine what the safe occupancy was. This number was based not only on the capacity calculations, but also on how many men could be safely put in without interfering with the oarsmen or compromising the stability of the boat. When this test was completed, the Board of Trade issued a load capacity plate which was applied to the bow of the lifeboat or, in the case of the Engelhardts, on the inside of the boat within view.

The final load capacities as seen on the plates of *Titanic*'s lifeboats were as shown previously in Table I. When the British Wreck Commissioner's Inquiry was

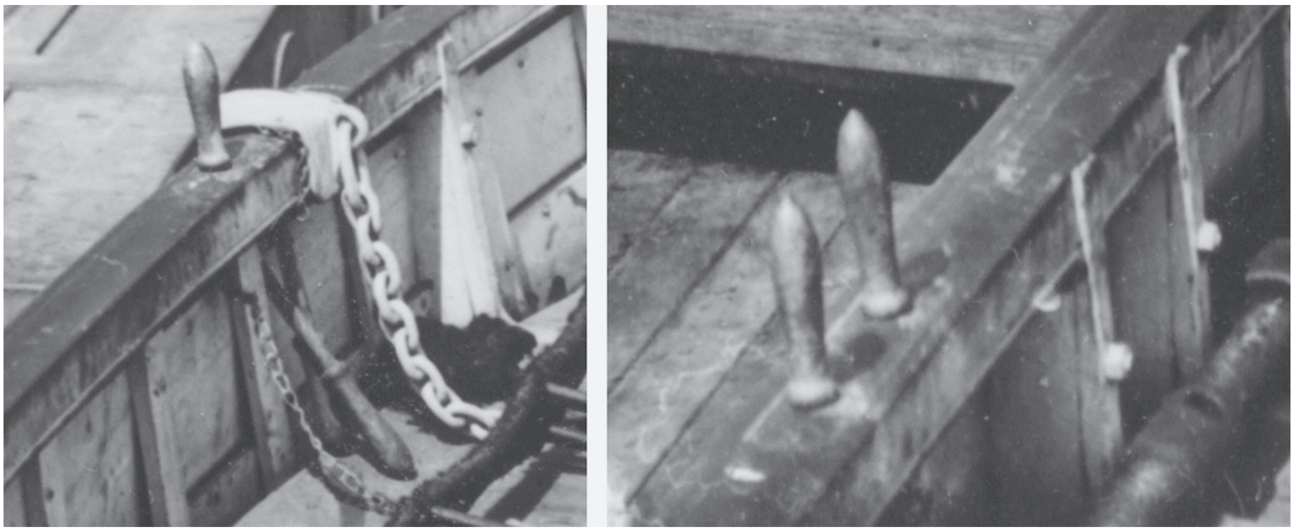


Fig. 23-38 **Thole Pins** – Thole pins were the vertical posts on the gunwales into which the oars were fitted. These images show typical thole pins as seen on other White Star Line lifeboats. The white-painted fitting with the chain in the left image is part of the gripe assembly used to secure the boat to the deck.

held, the Board of Trade was interested in the capacities specified in the survey document and not necessarily the numbers indicated on load plates. This was certainly the case considering an issue was made of under-filled lifeboats leaving the foundering *Titanic*.

BOAT EQUIPMENT

The type of equipment stowed within a lifeboat was determined by the class of vessel. Kept within the boats were some of the gear and provisions required such as oars, sails and masts, water, etc. Oil lamps, biscuits, and compasses were stored on the ship 'in some convenient place' ready for use as required. However, due to the circumstances of confusion and excitement at the time of sinking, many of the lifeboats were launched without these provisions. It must be remembered that there were no ship-wide lifeboat drills for the crew in 1912, nor was there any means by which the Bridge could communicate with the crews at the individual boats short of detailing someone to go to each boat to relay instructions.

Oil lamps for the fourteen main boats were brought out by the ship's Lamp Trimmer after a number of them had already been launched. These lamps were rectangular in shape, about 10in high, 6in square, and burned Colza oil.[7] The lamps intended for the emergency cutters were lit every night at 6.00 pm and were stowed in the wheelhouse.

Titanic's lifeboats were inspected and certified at Belfast. The following is a list of equipment that was provided per regulations:

The four Section A boats numbers 3, 4, 5 and 6 each were provided with:

Ten oars, all tipped
Two plugs (one plug hole), attached with chains
Two sets of thole pins attached to the boat by sound halyards
One sea anchor
Two balers
One rudder and tiller
One painter of 25 fathoms length
Two boat hooks
Two hatchets
Two water breakers, 10 gallon capacity each
Two dippers
One mast and sail
Lines becketed round outside of boat
One compass
One gallon of oil (vegetable or animal) and distributor
One lantern trimmed and filled with oil sufficient to burn for eight hours. (These were usually hung under an after thwart.) Copper air-case of 67.4 cubic ft capacity

The remaining ten boats, 7 through 16, were all equipped as above with the exception of having no lantern or oil distributor.

The two Section D boats (the emergency cutters) were provided with:

Six oars
Sixteen thole pins
One boat hook
Two plugs
One water breaker, 10 gallon capacity
One dipper
One sea anchor
One baler
One rudder and tiller
One painter of 25 fathoms length
One mast and sail

The four Engelhardt collapsible boats were provided with:

Eight oars
One and a half sets of rowlocks
Two steering crutches
One sea anchor
One boat hook
One painter of 25 fathoms length
One water breaker, 10 gallon capacity, and one dipper
Either one plug and one hand pump, or one pumps.

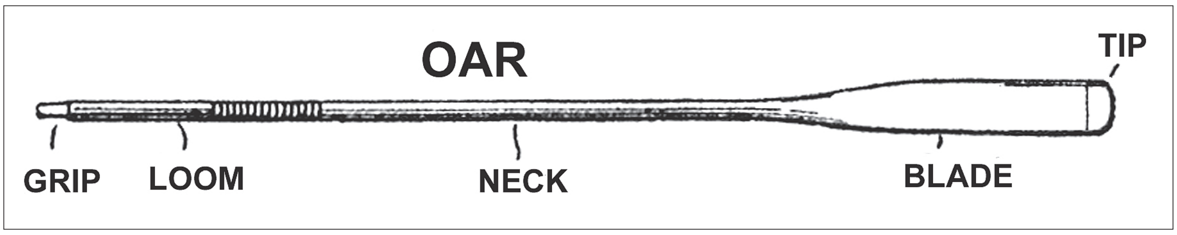


Fig. 23-39 **Lifeboat Oar**.

Oars

The oars were straight-grained ash with copper-tipped blades which were leather-bound in way of the crutches or thole pins. The lengths varied to suit the individual boat, the position of the thwart, and the height of the gunwale above water. The general rule for a double-banked boat was that the oar should be twice the length of the thwart from which they were used. A steering oar was limited to 16ft, was painted a distinctive color so as to be easily recognized and was usually about 1ft longer than the longest rowing oar supplied to the boat. Its blade was wider than an ordinary pulling oar. Of the ten oars recorded by Board of Trade Surveyor Francis Carruthers for the 30ft lifeboats, it is believed that six were 15ft long and four were 13ft in length. For the 25ft cutters six oars were provided, with two having a length of 12ft while the remaining four were 14ft. The Engelhardt collapsibles were to be equipped with a minimum of two oars at 13ft, four at 14ft and a 16ft steering oar. As seen in the specifications above, the Engelhardts had one extra oar than what was specified in period publications. The discrepancy may have been the steering oar.

Sea anchor

The purpose of the sea anchor was to allow the boat to ride steadily in a seaway with the bow pointed into the wind and seas. A sea anchor functioned on the principle that an object riding on the surface would be affected by the wind, whereas a submerged object would not; therefore, if a drogue-like object was submerged on a line from the bow, it would act as a drag and keep the bow facing into the wind. In doing so, the boat would take seas head-on and reduce the risk of capsizing. The common sea anchor was circular in section, no less than 24in in diameter, made from canvas and strengthened by hemp rope. Attached to the sea anchor was a stout rope trailer and a 20-fathom tripping line. The tripping line was used to turn the tail of the anchor towards the boat and enable it to be drawn on board. The hoop around which the canvas was secured was to be of suitable size for the purpose intended. Unfortunately, this pattern of anchor had an awkward shape for stowing in the lockers and would quickly deteriorate if left at the bottom of the boat.

The sea anchor was intended to be used in association with an oil distributor, which was designed to slowly release oil; a film of oil on the surface will calm rough seas. The oil-distributing apparatus was capable of distributing oil evenly and gradually on the surface of the water and was usually attached to the sea anchor. It consisted of a can or canvas bag with a metal spigot securely attached to the former, having a screw cap which could be adjusted to allow the oil to be distributed in suitable quantity.

Painter

A painter was basically a tow-rope. The painter could also be used to secure the boat to a ship under way to keep the tension off the falls, so that they could be disengaged. Each boat was provided with a painter no less than 20 fathoms in length.

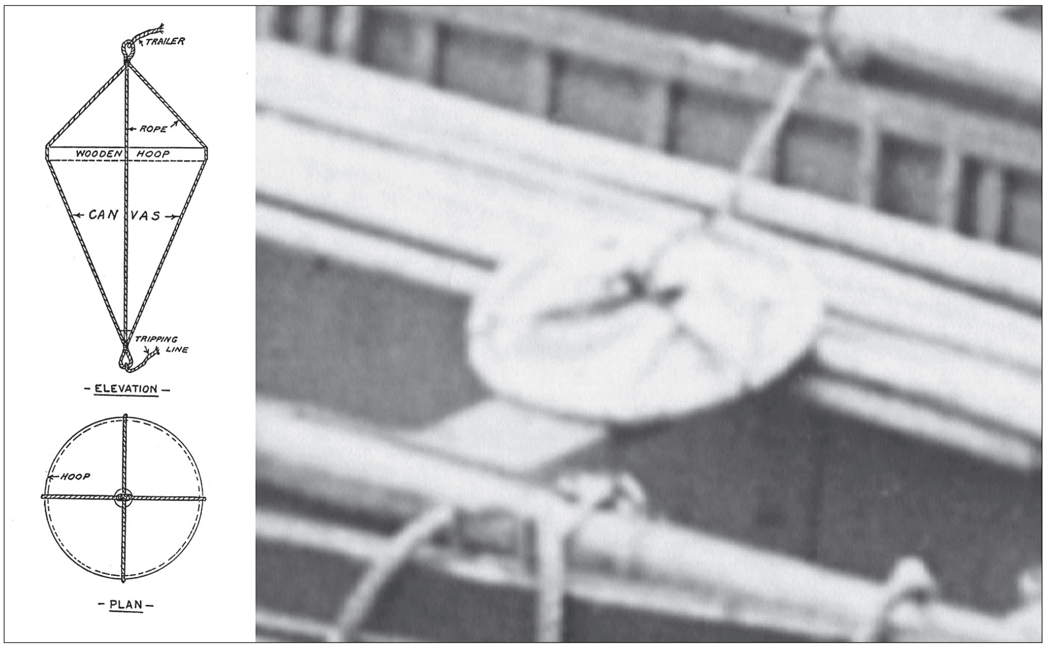


Fig. 23-40 **Sea Anchor**. *(Illustration from authors' collection; image from Josha Inglis Collection)*

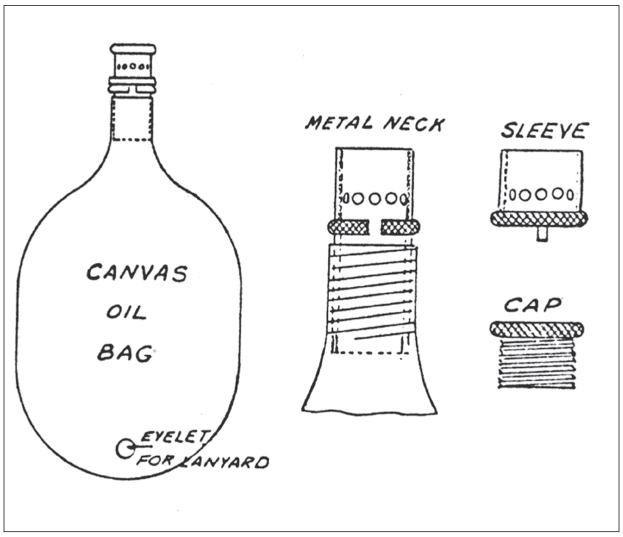


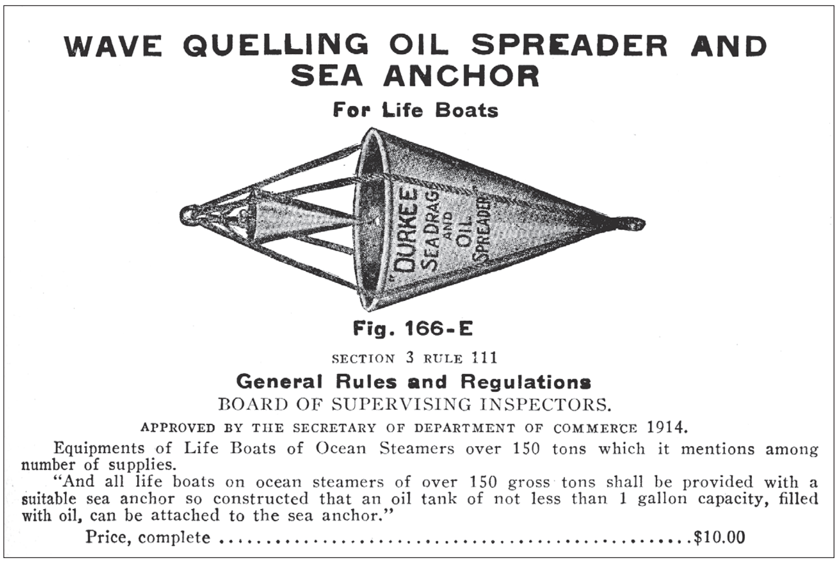
Fig. 23-41 **Oil Distributor** – A common oil distribution vessel for attachment to the sea anchor. Other versions did exist, and *Titanic*'s may not have been of this type. *(Ship's Boats/Authors' collection)*

Water breaker

Usually there were two vessels for holding fresh water placed in each boat, each containing a quantity of water for each person the boat was certified to carry. New breakers were filled immediately after being supplied to a boat, in order that the wood could swell and become watertight. They were neatly stowed in cradles on each side of the keelson, clear of the lower seats, and lashed to eye-plates to prevent them being lost overboard. The dippers were attached to the breakers and weighted so as to allow the mouth to be submerged below the surface of the water.

Provision tanks

Airtight metal provision tanks were provided to contain biscuits for the boat occupants. The tanks were usually


"DURKEE
SEA DRAG
AND
OIL
SPREADER"

WAVE QUELLING OIL SPREADER AND SEA ANCHOR

For Life Boats

Fig. 166-E

SECTION 3 RULE 111

General Rules and Regulations

BOARD OF SUPERVISING INSPECTORS.

APPROVED BY THE SECRETARY OF DEPARTMENT OF COMMERCE 1914.

Equipments of Life Boats of Ocean Steamers over 150 tons which it mentions among number of supplies.

"And all life boats on ocean steamers of over 150 gross tons shall be provided with a suitable sea anchor so constructed that an oil tank of not less than 1 gallon capacity, filled with oil, can be attached to the sea anchor."

Price, complete $10.00

Fig. 23-42 **Sea Anchor with Oil Distributor** – This illustration from an American catalogue shows a sea anchor rigged with one means of distributing oil.

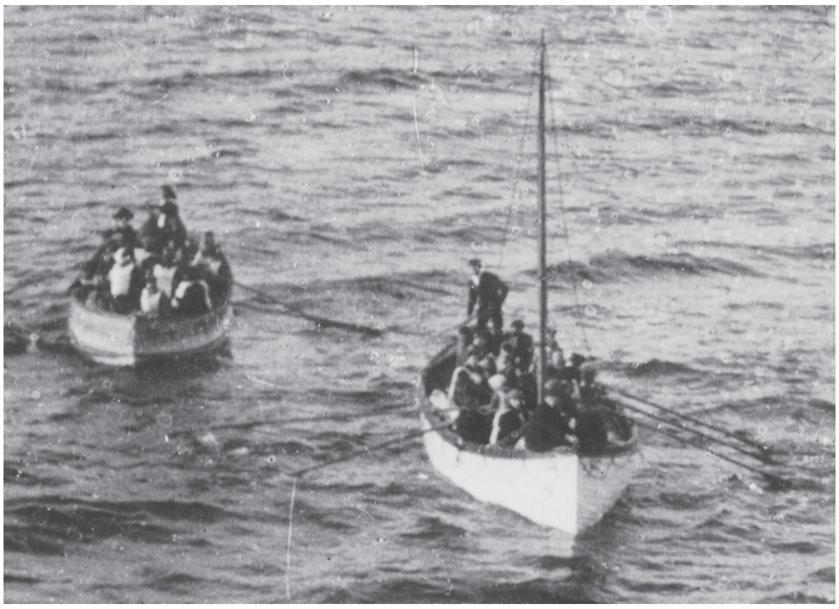


Fig. 23-43 **Boat No.14 with Collapsible Lifeboat** – Lifeboat No.14 with Collapsible D in tow, as seen here approaching *Carpathia*. *(National Archives)*

fitted under a thwart or in a storage locker. Watertight metal screw caps no less than 6in in diameter were fitted to the tanks; the openings were large enough to allow a person's arm to reach the remotest corner of the tank. For opening the brass cap, a key or lever was supplied and was attached to the boat by lanyard or chain. The material used was galvanized sheet iron, durable and of strong scantling. These biscuit or bread tanks were a compulsory regulation after 1913.

Compasses

Titanic's 30ft lifeboats were supplied with Lord Kelvin's spirit compasses and suitable containers. Accommodation was made for the reception of the compass so that it could be protected from the weather and still be in such a position that the coxswain could steer the boat without difficulty. It was common to secure a small box under the after thwart immediately in front of the stern sheets with a hinged front, or, in the case of *Titanic*'s boats, to fasten it to cleats on the top of the thwart. *Titanic* was equipped with fourteen of these compasses.

Fenders

Canvas-covered pads were provided to cushion the boat against contact with the side of a ship, a dock, or other boats. These were square in shape and filled with cork, and were provided to *Titanic* although not required by regulations.

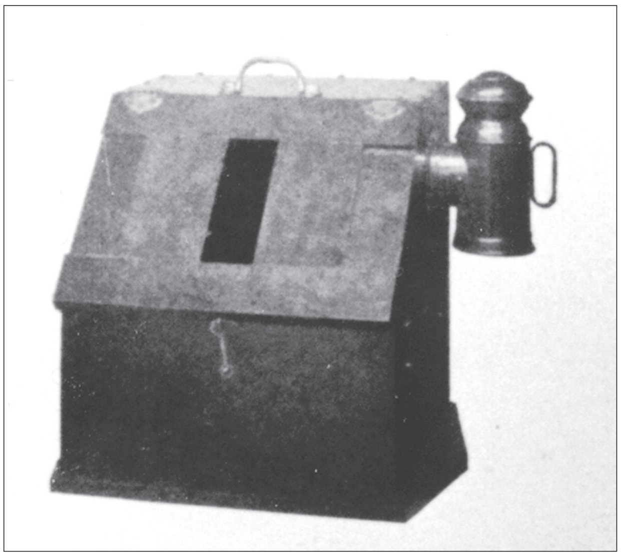


Fig. 23-44 **Spirit Compass** – A period Kelvin spirit compass in a wooden case with an oil lamp attached to the side.

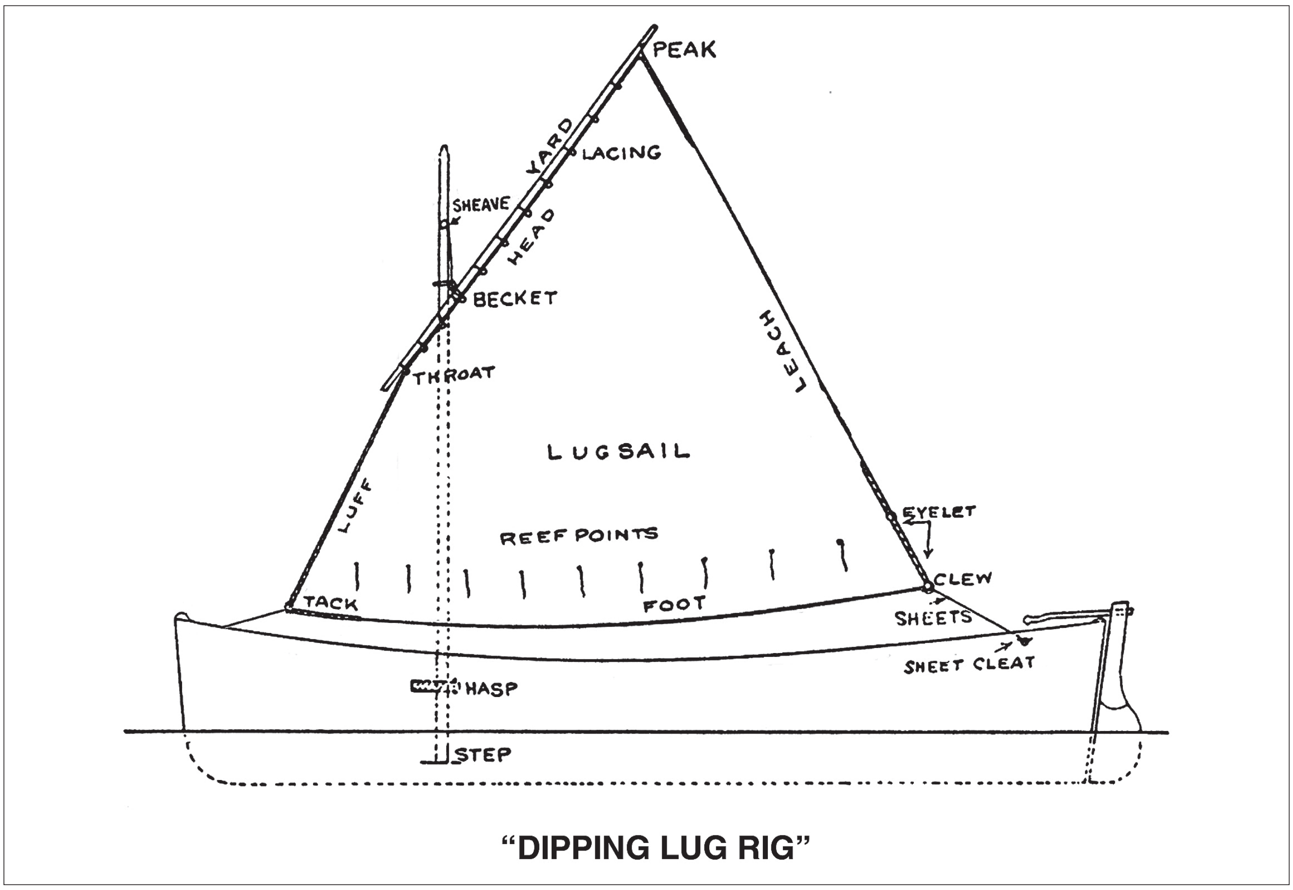
Sails

Titanic's boats were provided with masts and sails stowed within painted canvas bags, along with proper gear for each. Masts were designed to be not more than two-thirds the length of the boat; the sails were required to be of good quality duck (canvas) of suitable size, with each sail fitted for reefing.[8] The boats were of sufficient stability, even in a fully loaded condition, to carry a sufficient spread of sail in a fresh breeze.

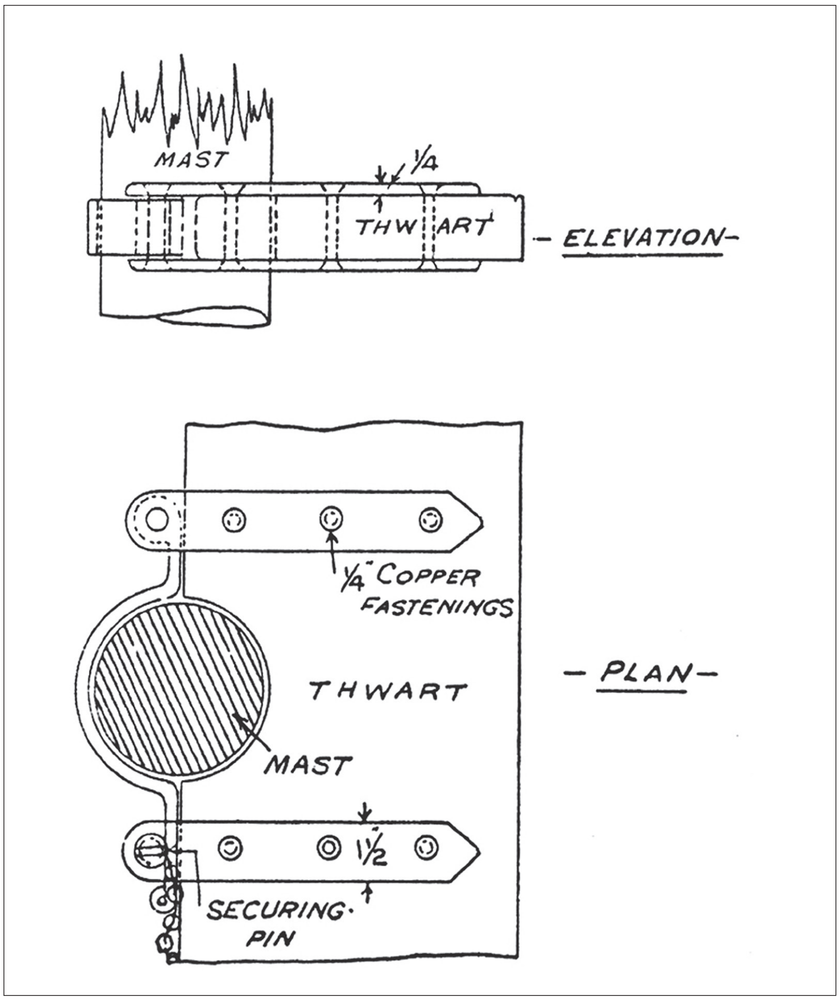
The sail rig was a type known as a 'dipping lug rig'. This design was common on open boats and would not have varied from long-standing boat rigging practices. Both the 30ft and 25ft lifeboats had sail rigs; the Engelhardt collapsibles did not.

The lifeboats recovered by the *Carpathia* were brought back to New York and secured within the White Star Line's berth. The following inventory of the contents was taken by the C.M. Lane Lifeboat Co. of Brooklyn:[9]

Boat No.1 (25ft cutter) – 5 oars; 1 fender; 1 catch (sea) anchor; mast, sail and rigging; 1 rudder; 1 water keg; 7 thole pins; 2 boat painters.
Boat No.2 (25ft cutter) – 1 sail cover; 1 catch anchor; 1 dipper; 3 oars; 1 water keg; 2 boat painters. (The thole pins were missing.)
Boat No.3 (30ft main boat) – mast, sail and rigging; 8 oars; 1 boat hook; 1 rudder; 2 water kegs; 1 catch anchor; 9 oar pins; 1 wrench; 1 provision tank; 2 boat painters.
Boat No.5 (30ft main boat) – mast, sail and rigging; 1 rudder; 8 oars; 1 boat hook; 1 sail cover; 2 water kegs; 1 catch anchor; 1 provision tank; 27 oar pins.
Boat No.6 (30ft main boat) – 1 boat hook; 1 catch anchor; 2 water kegs; 5 oars; 1 rudder; 29 thole pins; 1 provision tank; 2 boat painters.
Boat No.7 (30ft main boat) – mast, sail and rigging; 1 rudder; 1 oil can; 10 oars; 2 boat hooks; 2 water kegs; 2 dippers; 1 catch anchor; 21 thole pins; 1 wrench; 1 provision tank; 1 boat painter.
Boat No.8 (30ft main boat) – masts, sail and rigging; 9 oars; 1 boat hook; 1 rudder; 2 water kegs; 1 dipper; 1 catch anchor; 21 thole pins; 1 lamp; 1 provision tank; 1 boat painter.
Boat No.9 (30ft main boat) – mast, sail and rigging; 11 oars; 2 boat hooks; 1 catch anchor; 1 rudder; 16 thole pins; 2 dippers; 2 water kegs; 1 wrench; 1 provision tank.
Boat No.10 (30ft main boat) – mast, sail and rigging; 25 thole pins; 2 catch anchors; 2 water kegs; 10 oars; 2 boat hooks; 1 rudder; 1 dipper; 1 provision tank.
Boat No.11 (30ft main boat) – mast, sail land rigging; 4 oars; 1 wrench; 2 water kegs; 1 oil can; 1 catch anchor; 28 thole pins; 1 provision tank; 2 boat painters.


PEAK
YARD
LACING
SHEAVE
HEAD
BECKET
THROAT
LEACH
LUGSAIL
LUFF
REEF POINTS
EYELET
CLEW
TACK
FOOT
SHEETS
SHEET CLEAT
HASP
STEP
"DIPPING LUG RIG"

Above Fig. 23-45 **Rigging Diagram for Lifeboat** – This rigging diagram illustrates a common open lifeboat with its lug sail raised.


MAST
1/4
THWART
– ELEVATION–
1/4" COPPER FASTENINGS
THWART
– PLAN–
MAST
1 1/2
SECURING-PIN

Left Fig. 23-46 **Mast Clamp** – This illustration shows the mast clamp which was mounted to the after side of the second thwart aft of the stem. *(Ship's Boats/Authors' collection)*

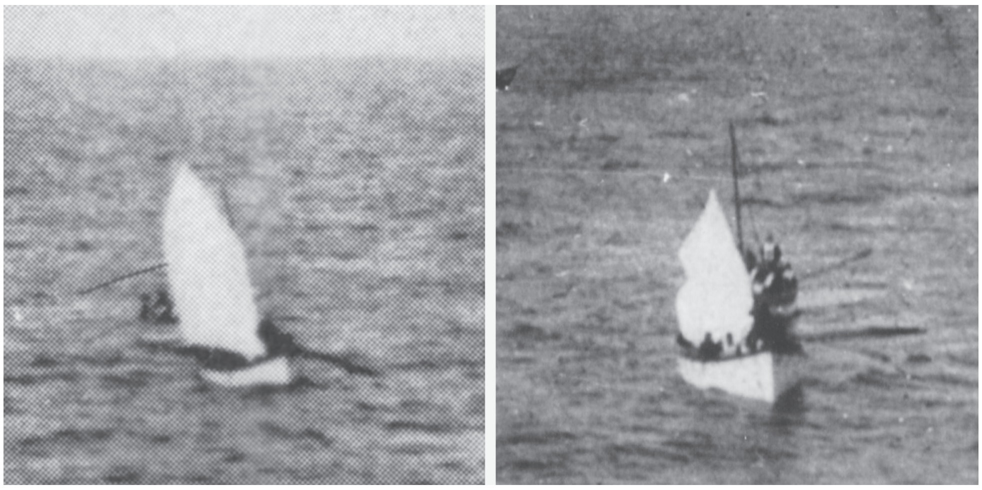


Fig. 23-47 ***Titanic* Lifeboat Under Sail** – In these two images, a lifeboat is seen here while in the process of lowering the lug sail. This was Boat No.14, commanded by 5th Officer Harold Lowe; Collapsible D, in tow, is nearly obscured by the sail. *(Left image from authors' collection; right image from National Archives)*

Boat No.12 (30ft main boat) – mast, sail and rigging; 23 thole pins; 1 catch anchor; 2 water kegs; 2 boat hooks; 7 oars; 1 rudder; 1 dipper; 1 wrench; 1 provision tank.

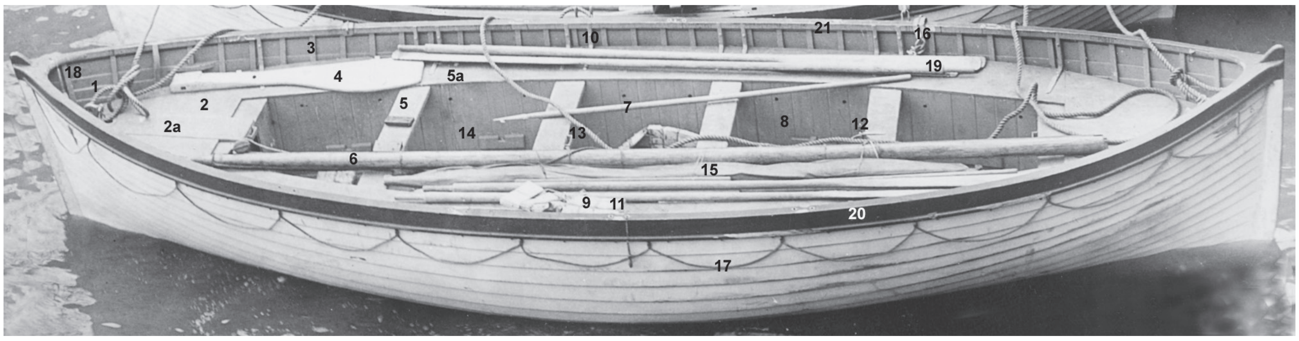
Boat No.13 (30ft main boat) – mast, sail and rigging; 1 oil can; 1 rudder; 2 boat hooks; 10 oars; 2 water kegs; 1 catch anchor; 1 dipper; 21 thole pins; 1 provision tank; 1 boat painter.

Boat No.16 (30ft main boat) – mast, sail and rigging; 1 rudder; 2 dippers; 15 thole pins; 2 water kegs; 10 oars; 2 boat hooks; 1 wrench; 1 provision tank.

Below Fig. 23-49 **Overview of Lifeboat Fittings** – In this close-up of one of *Titanic*'s 30ft lifeboats, the various parts, fittings and supplies have been called out as indicated here. *(Josha Inglis collection)*

1. Hook for Murray's Disengaging Gear
2. Stern sheet
2a. Gangboard
3. Timber
4. Rudder
5. Thwart with compass chocks attached
5a. Side bench
6. Mast with sheave attached
7. Boat hook
8. Tank cleading
9. Life Jacket
10. Knee
11. Thole pin holes with one thole pin hanging from chain
12. Mast clamp
13. Clamp for brace accommodating ridge spar
14. Cleat for foot spar
15. Sail
16. Gripe
17. Grab line
18. Steering crutch hanging from chain
19. Oar
20. Sheer strake
21. Gunwale

Above Fig. 23-48 ***Titanic*'s Lifeboats at New York** – *Titanic*'s remaining lifeboats lay tied up at the White Star Line berth after being offloaded from the *Carpathia*. *(The Daily Sketch/Ray Lepien collection)*



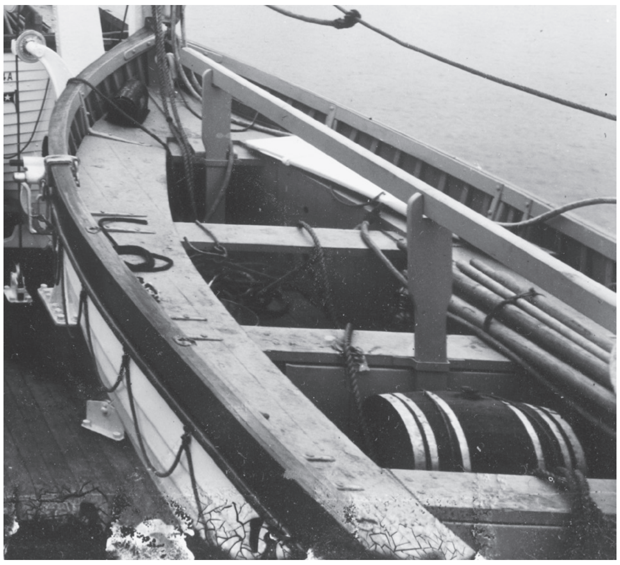


Fig. 23-50 **Ridge Spar** – A ridge spar from one of the lifeboats of the *Georgic*. The ridge spar was supported by braces fit into clamps on the thwarts and provided a peak for the canvas cover in order that rain would run off. *(H&W/Authors' collection)*

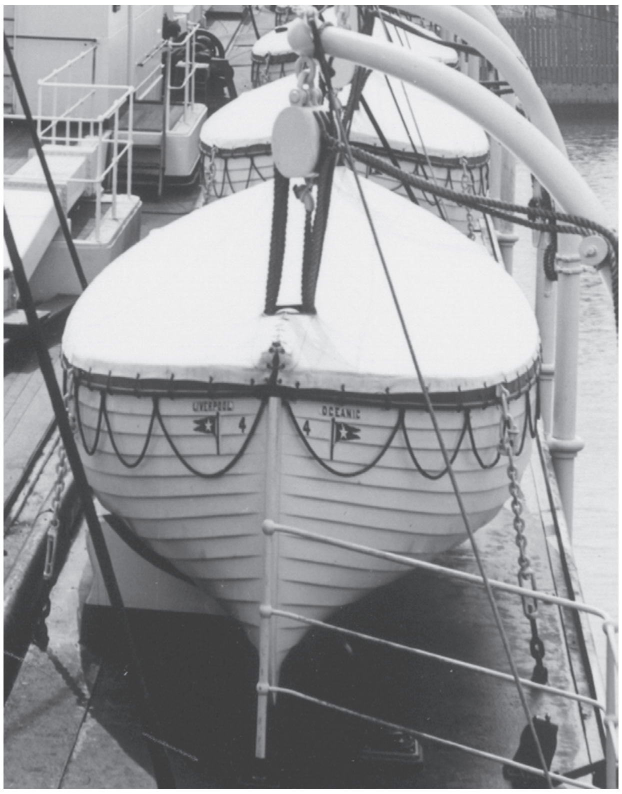


Fig. 23-51 **Lifeboat Fitted with Canvas** – One of *Oceanic*'s lifeboats with its canvas cover in place. This cover is obviously new, as the canvas is nearly white. *(H&W/Authors' collection)*

Stowage of boats on deck

Ridge spars were fitted to each boat, supported by uprights from the keelson at the center and two struts from the gunwale. The purpose of the spar was to support the canvas or portable wooden covers which protected the interior of the boats from the weather while stowed on the Boat Deck. The canvas cover was fitted over in one piece and secured with lashings through eyelets to solid brass knobs fixed to the underside of the rubbers.

Fourteen of the main boats and all four of the Engelhardt collapsibles were stowed on the deck in chocks. The wooden chocks were formed to fit the underside shape of the boat hull as they acted as 'stands', while the keels of the boats were kept in place via iron clips attached to the chock assembly. The two cutters were always in the hanging position, swung outboard and lashed securely to the side of the superstructure, except in port where they were brought inboard over the Boat Deck.

The patented single-stowing chocks for the 30ft main boats were supplied by the Welin Davit and Engineering Co., and could be positioned in one of two locations on the deck, inboard or outboard. The position of the stowage chocks in relation to the davits was such that the heads of the latter plumbed the lifting hooks in the boat. In order to keep a wide passage between the lifeboats and machinery casings, many lifeboats were stowed outboard of a vertical line from the davit head. The position of the davit head and heel in relation to the lifting hook was such that the weight of the boat, when the vessel was upright, enabled it to swing easily into the outboard position. The keels of the boats were held to the chocks with iron keel clips, which could be disengaged by a lever on the chocks. The chocks were the folding type and could be kicked down after being disengaged from the vertical position by a pin. This design enabled the boats to be lowered overboard without having to first hoist them up by hauling on the falls.

The boats were secured to their chocks by chain gripes on the inboard sides of the boats. The outboard sides of the boats were not fastened down. However, eyes were fitted along the side of the superstructure to accommodate rope lashings. These were never seen in use aboard *Titanic*, but were seen utilized in at least one picture of *Olympic* on her maiden voyage.

Two of the Engelhardts were stowed on the Boat Deck and two on the roof of the Officers' Quarters deckhouse abeam of the No.1 Funnel. They were secured on deck with chain gripes on both sides and rested on conventional double-sided chocks.

Protective fencing was fitted around the lower part of the main boats and within the spaces between the hulls and the davit frames. These were portable and attached within deck sockets, and were intended to prevent anyone from slipping or being washed overboard.

The Welin Quadrant Davit

Titanic was fitted with sixteen sets of double-acting quadrant davits manufactured by the Welin Davit and

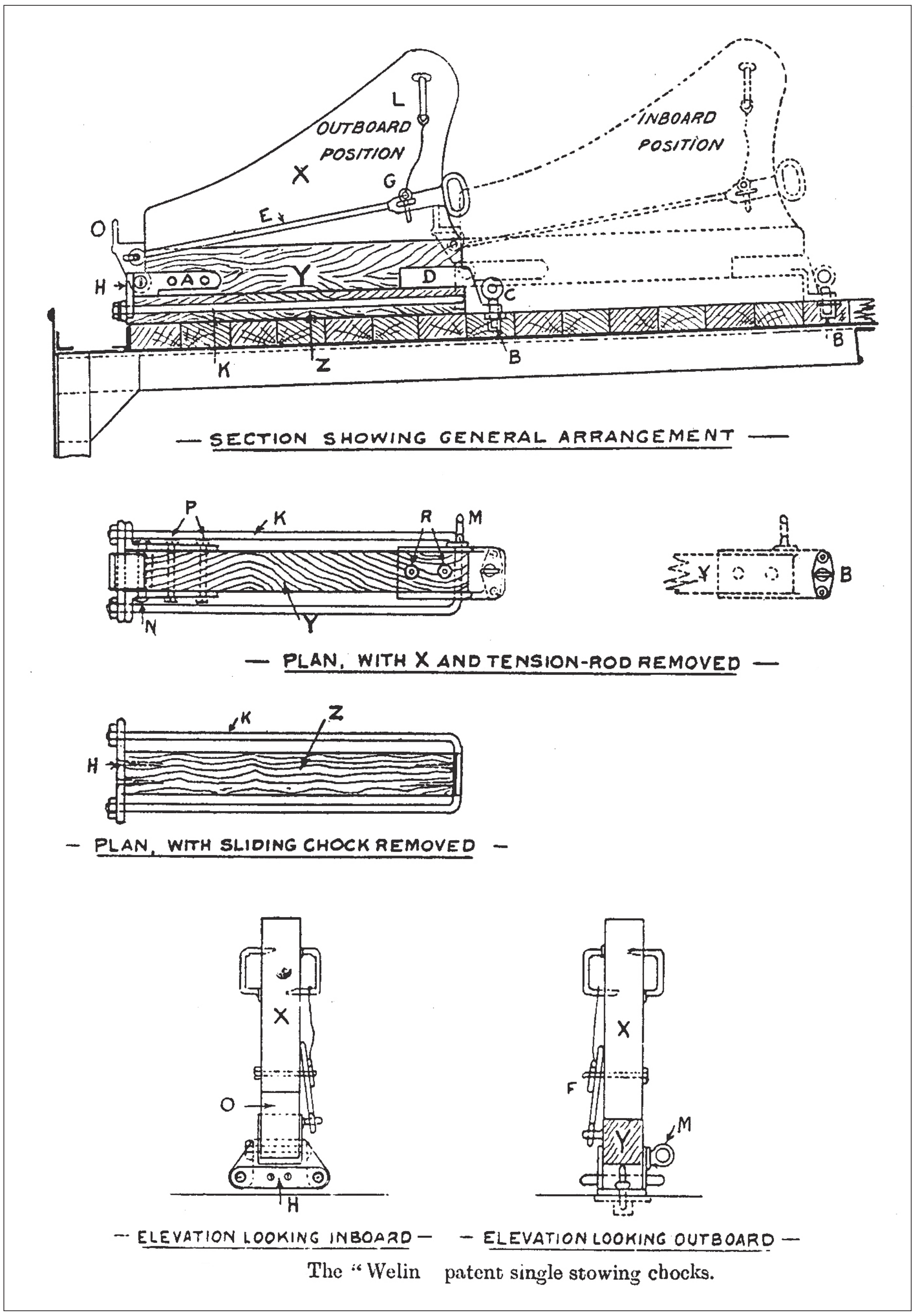

L
OUTBOARD POSITION
INBOARD POSITION
X
G
E
O
H
A
Y
D
C
B
K
Z
B
— SECTION SHOWING GENERAL ARRANGEMENT —
P
K
R
M
N
Y
B
— PLAN, WITH X AND TENSION-ROD REMOVED —
K
Z
H
— PLAN, WITH SLIDING CHOCK REMOVED —
X
O
H
X
F
M
Y
— ELEVATION LOOKING INBOARD —
— ELEVATION LOOKING OUTBOARD —
The " Welin patent single stowing chocks.

Fig. 23-52 **Welin Chock** – A Welin chock of the type used on *Titanic,* albeit with slight variations in design.

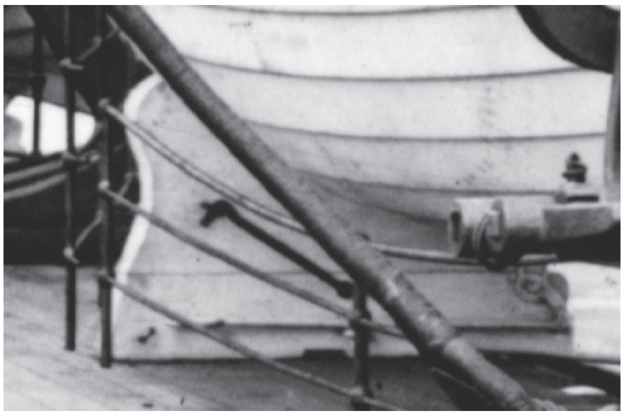


Fig. 23-53 **Welin Chock** – A Welin chock fitted beneath one of *Olympic*'s boats.

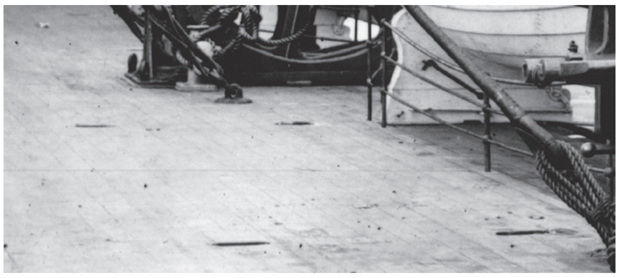


Fig. 23-54 **Deck Sockets for Chocks** – Brass sockets in the deck allowed to chocks to be positioned either in the inboard or outboard positions. This photograph also shows one of the guard fences that prevented passengers or crew from slipping under the lifeboats.

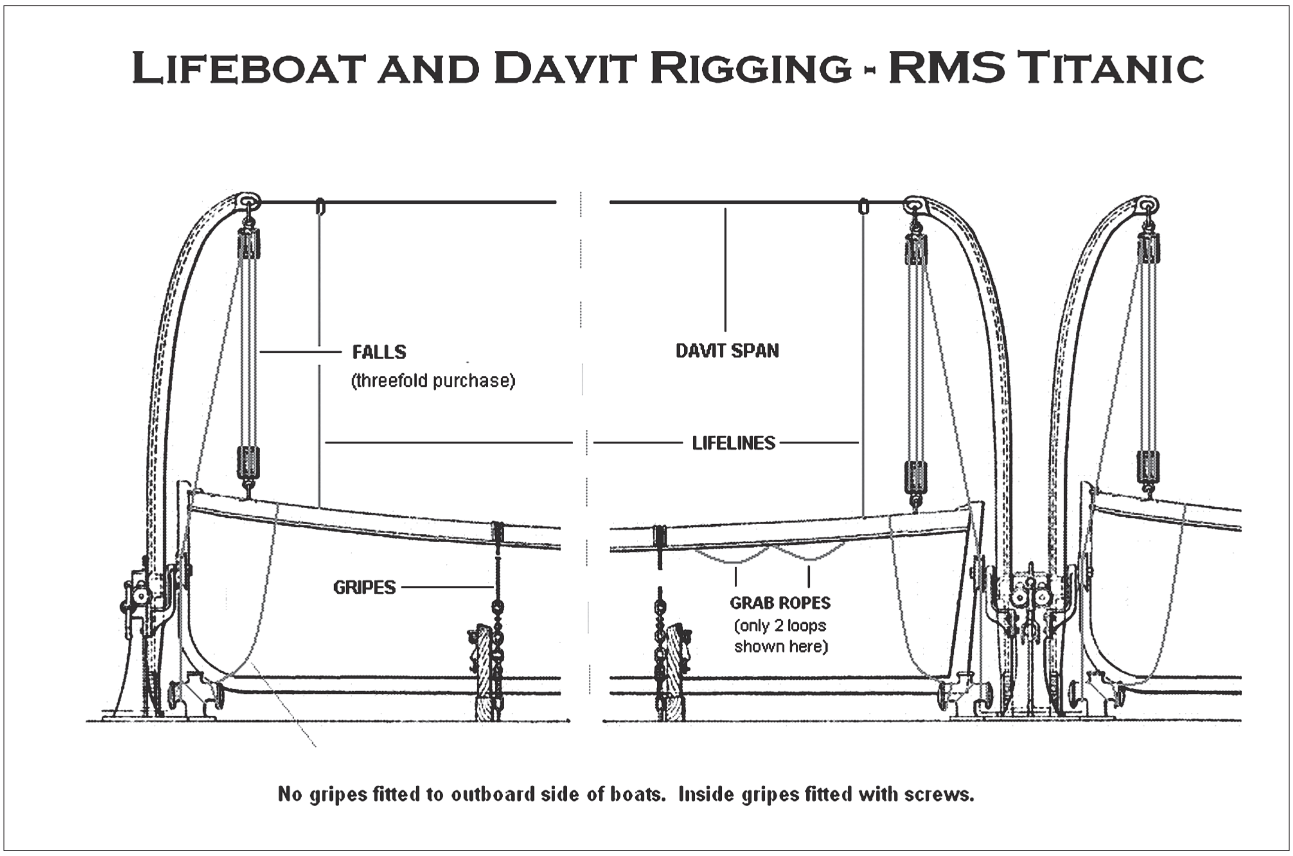

LIFEBOAT AND DAVIT RIGGING - RMS TITANIC
FALLS
(threefold purchase)
DAVIT SPAN
LIFELINES
GRIPES
GRAB ROPES
(only 2 loops shown here)
No gripes fitted to outboard side of boats. Inside gripes fitted with screws.

Fig. 23-55 **Davit Rigging**. *(Illustration by Art Braunschweiger)*

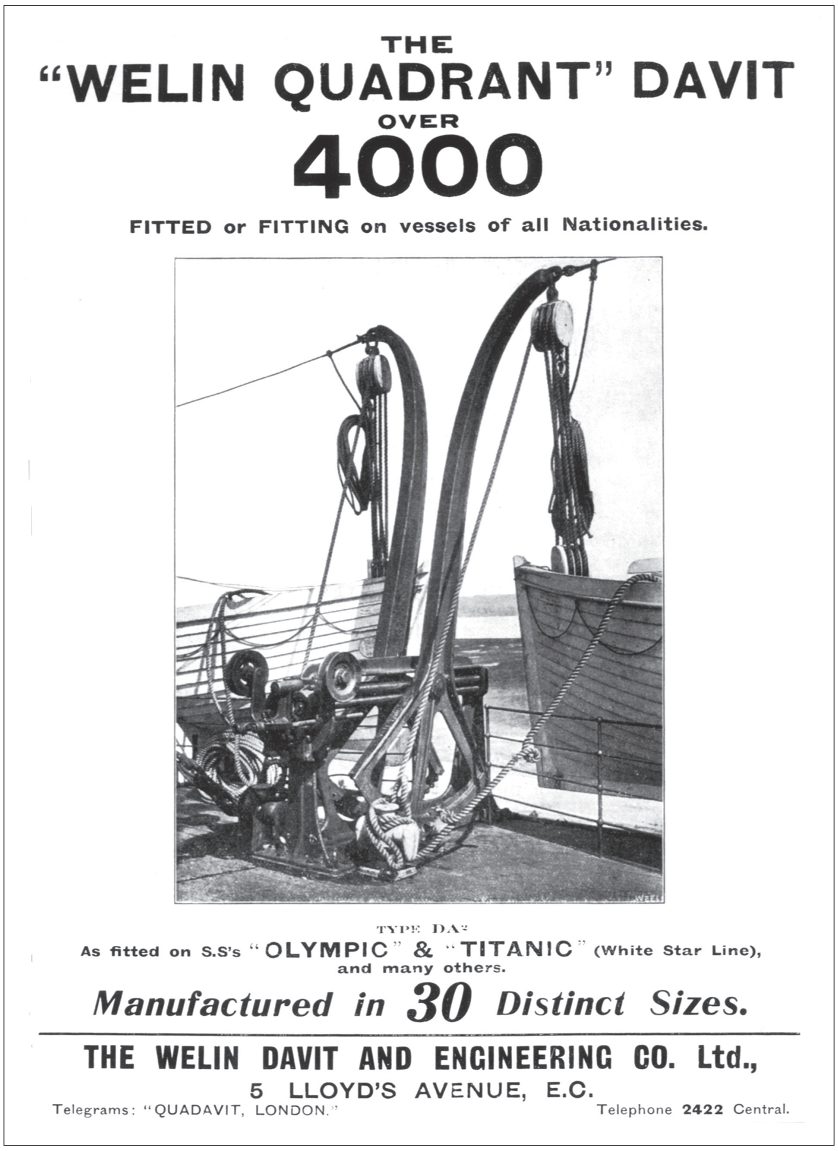
Engineering Co., London. The Welin davits had long cast-steel arms intended to carry a boat well over the side of the ship; these could also accommodate the stowing of lifeboats one on top the other, and/or inboard of each other. Although this extra capacity was not used on *Titanic*, it would be employed on *Olympic* later in her career.

With the Welin davit, boats could be swung out from many different athwartship positions, whether the boats were positioned directly between the davits or inboard of them. The spacing between the davit arms equaled the distance between the forward and after ends of each boat. The bases of the davit arms were cast in the shape of a quadrant and fitted with teeth which engaged with a corresponding toothed casting at the base of the davit frame. The davits were doubled up in that one frame held the forward arm of one boat and the after arm of the boat next to it; the end davit frames held a single arm. The shared-arm arrangement meant that only every other boat on one side of the ship could be swung out at a time. A hand crank was stowed by removing it from the center drive shaft and turning it around backwards, so that the end rested on one of the pulley mounts. In the center of the crank was a square hole that fit over the square end of the shaft. To keep the crank from being misplaced or carried off, there was a small chain connecting the crank to the davit frame.

Design, construction and use

The arm gear had a disengaging mechanism which engaged the teeth to activate the intended arm for use. The driving-pinion for the screw gear was carried on a swinging frame, the lower end of which was forked. Between the limbs of the fork was an eccentric, which could be thrown over by hand so that the pinion meshed with the gear of whichever screw it was desired to operate. This eccentric had a throw somewhat greater than that corresponding to its maximum eccentricity, so that it remained automatically locked when thrown over one way or the other.

The design of the davit was simple and admirably effective. To understand what happened as the arm was raised and lowered, mentally extend the curve at the bottom of the arm (the quadrant) into a complete circle. The pivot point (screw block) would be at the exact center of that circle. As the screw was turned, the screw block traveled forward or backwards, always staying at the same height. To prevent slippage, a rack (row of teeth) on the davit frame meshed with teeth on the inner edge of the quadrant. The outer edge of the quadrant had a wider rim without teeth. The weight of the boat forced the quadrant towards the centerline of the davit frame, ensuring that the teeth always meshed and that the arm stayed locked in position. The arms had the ability to swing at angles of almost 90° from inboard to outboard.



THE
"WELIN QUADRANT" DAVIT
OVER
4000
FITTED or FITTING on vessels of all Nationalities.

TYPE DA^2
As fitted on S.S's "OLYMPIC" & "TITANIC" (White Star Line), and many others.

Manufactured in 30 Distinct Sizes.

THE WELIN DAVIT AND ENGINEERING CO. Ltd.,
5 LLOYD'S AVENUE, E.C.
Telegrams: "QUADAVIT, LONDON." Telephone **2422** Central.

Fig. 23-56 **Advertisement for the Welin Davit and Engineering Co. Ltd.** (The Shipbuilder/*Authors' collection)*

Covering the screws was a canvas sheath which kept the screws as free from dirt and corrosion as possible. This appears to have been a permanent attachment as photos show it in place in a variety of arm positions.

The boats were lowered by hand with the assistance of the specially-shaped bitts fastened to the deck near each davit assembly. By taking a series of turns with the falls around and across the bitts at each end, the weight of a fully-loaded boat was reduced to manageable levels for only a few deckhands. However, lowering in this manner was not without some difficulty. During *Titanic*'s sinking, there were cases where the forward and after ends of the boats were not lowered at the same rate.[10] Additionally, there were instances of the falls becoming tangled and halting the lowering of one end; lowering a lifeboat from the height of the Boat Deck to the water required several hundred feet of line to be paid out.

The process of raising the boats from the water when launched for drills was accomplished by electric winches on the Boat Deck.

The davits' designer, Axel Welin, intended *Titanic* to carry thirty-two lifeboats. He presented this lifeboat accommodation plan for *Olympic* and *Titanic* to a gathering of ship owners and underwriters in Scotland on May 25, 1910. Given the utility of the davit design, in actuality *Titanic* could have carried up to sixty-four lifeboats rather than the twenty she was ultimately equipped with. Much has been made of this point, and authors frequently write with disbelief over the fact that *Titanic*'s passenger and crew compliment exceeded her lifeboat capacity by such a wide margin. However, this must be considered in the context of the time; in 1912, the transatlantic sea lanes were frequented by many ships. At the time, it was considered inconceivable that a ship could ever founder with such rapidity that all persons would need to be taken off at once, rather than ferrying passengers to other vessels and then returning for additional loads. Even after the *Titanic* disaster, the idea of 'lifeboats for all' was not universally held. The author of *Practical Shipbuilding* – this book being

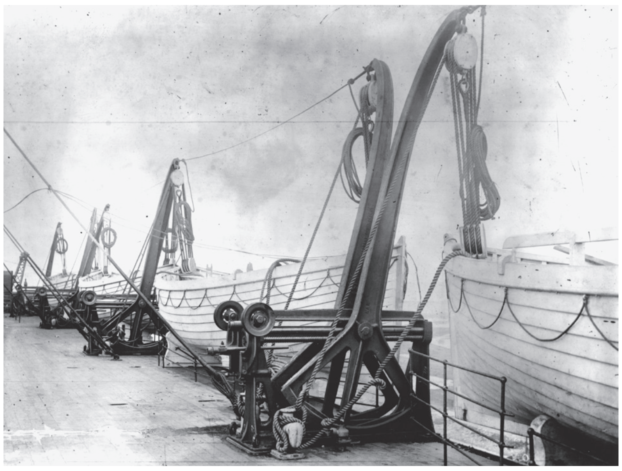


Fig. 23-57 **Welin Davits** – The Welin Davits on *Olympic* before they were painted.

a widely-known and highly-regarded work on the subject – wrote, in his 1918 edition:

> *It may be pointed out that, of the six million passengers who crossed [the Atlantic] in the ten years ending June, 1911, there was only a loss of six lives. The fact that Titanic carried boats for little more than half the people on board was not a deliberate oversight, but was in accordance with*

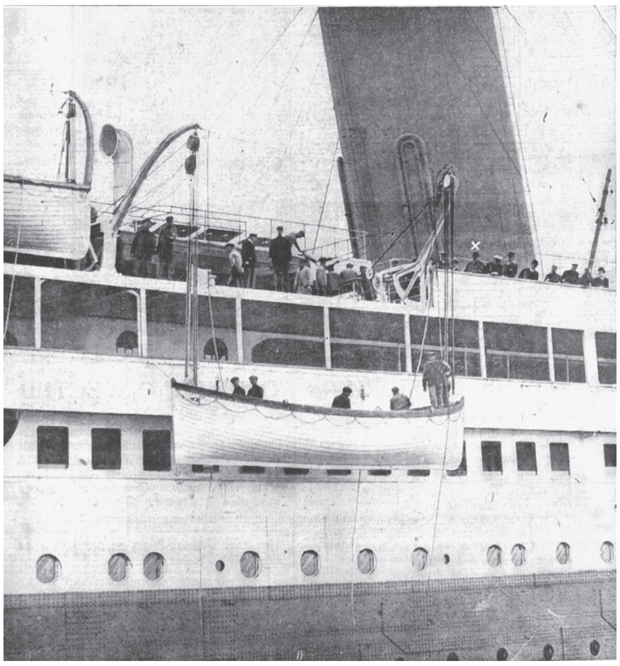


Fig. 23-58 **Davits in Use** – After *Titanic*'s sinking, *Olympic* was inspected at New York by Senator William Alden Smith, who presided over the American hearings. In this scene, Boat No.9 is lowered to demonstrate what it would have been like on the morning of April 15. *(Ray Lepien collection)*

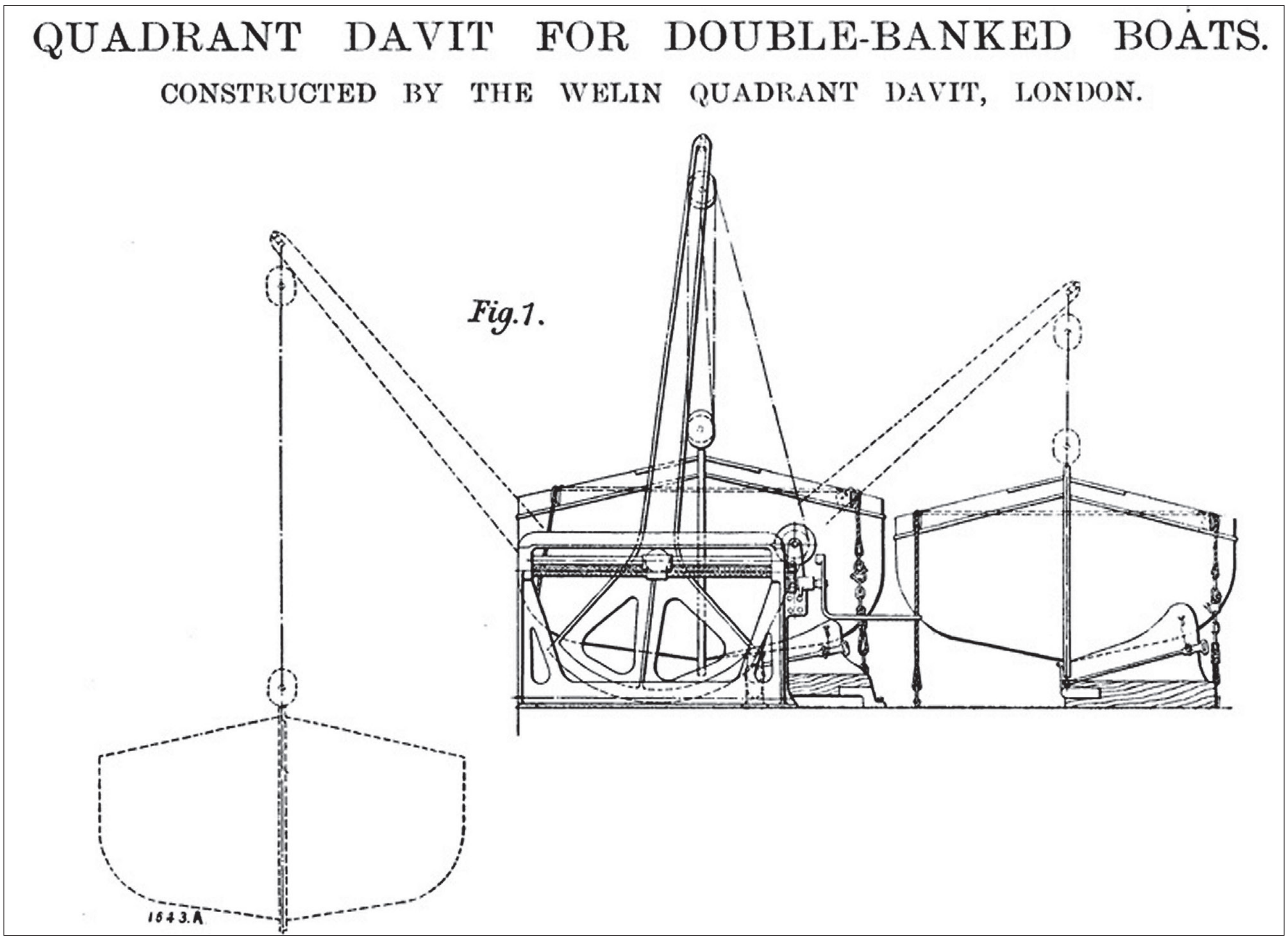

QUADRANT DAVIT FOR DOUBLE-BANKED BOATS.
CONSTRUCTED BY THE WELIN QUADRANT DAVIT, LONDON.
Fig. 1.
1643.A

Fig. 23-59 **Illustration of Quadrant Davits in Use** – This illustration shows the range of motion of a double-acting quadrant davit, and also indicates how these davits could readily accommodate a second set of lifeboats stored inboard.

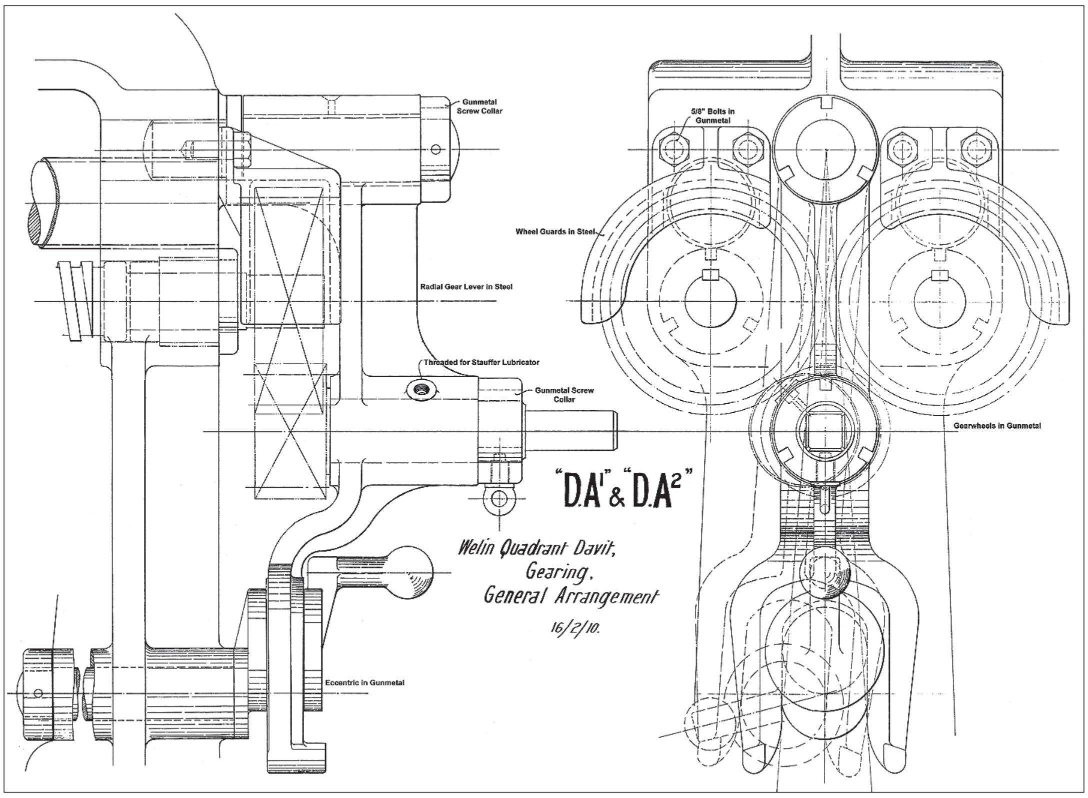

Gunmetal Screw Collar
5/8" Bolts in Gunmetal
Wheel Guards in Steel
Radial Gear Lever in Steel
Threaded for Stauffer Lubricator
Gunmetal Screw Collar
Gearwheels in Gunmetal
"D.A1" & "D.A2"
Welin Quadrant Davit,
Gearing,
General Arrangement
16/2/10.
Eccentric in Gunmetal

Fig. 23-60 **Gearing Arrangement for Welin Davits**. *(Illustration by Bruce Beveridge based on original drawing)*

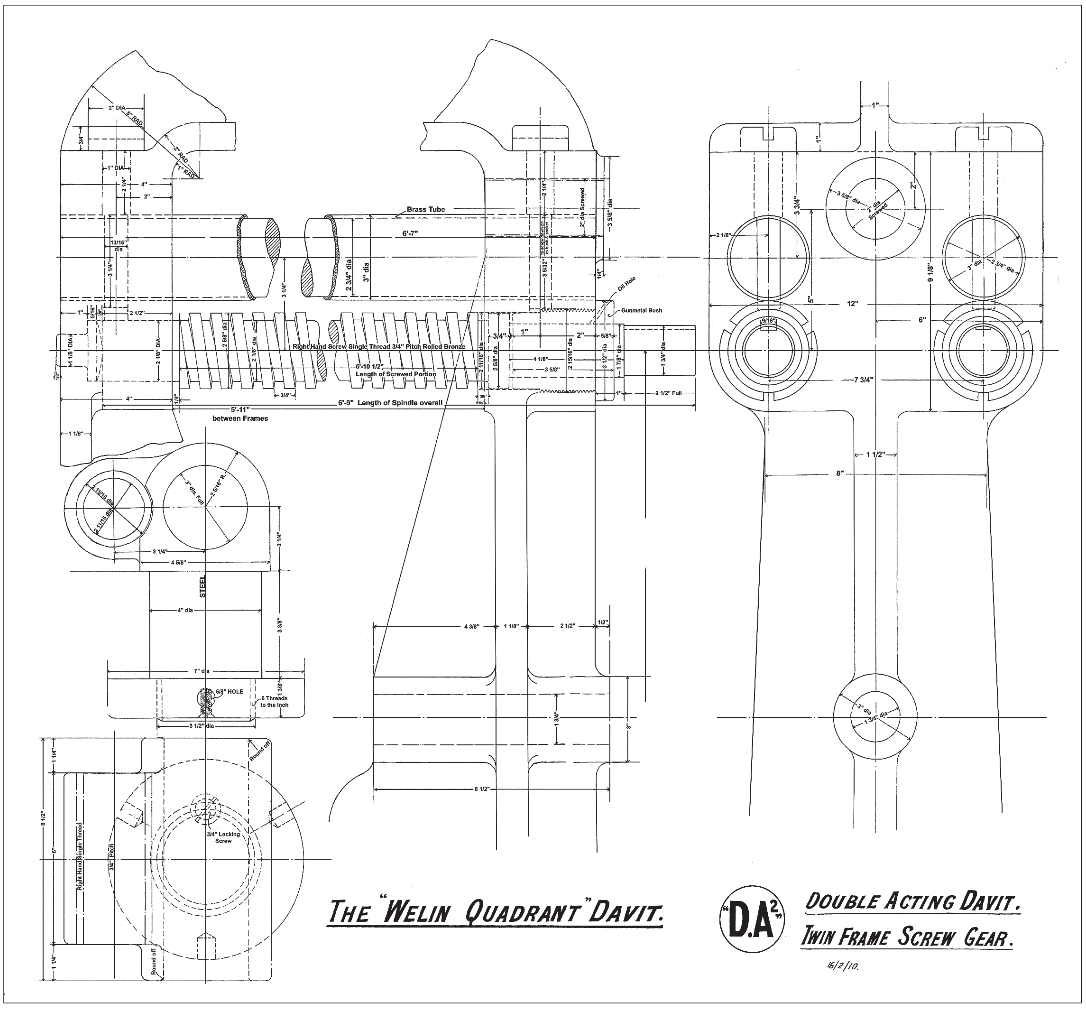

2" DIA
5" RAD
2" RAD
1" RAD
1" DIA
Brass Tube
6'-7"
2 3/4" dia
3" dia
2" dia Screwed
3 5/8" dia
to screw down on to bush & socket
Oil Hole
Gunmetal Bush
Right Hand Screw Single Thread 3/4" Pitch Rolled Bronze
5'-10 1/2" Length of Screwed Portion
6'-9" Length of Spindle overall
5'-11" between Frames
2 1/2" Full
2 15/16 dia
2 11/16 dia
3" dia. Full
2 5/16" R.
STEEL
4" dia
7" dia
5/8" HOLE
6 Threads to the Inch
3 1/2" dia
Round off
Right Hand Single Thread
3/4" Pitch
3/4" Locking Screw
Round off
THE "WELIN QUADRANT" DAVIT.
"D.A2"
DOUBLE ACTING DAVIT.
TWIN FRAME SCREW GEAR.
16/2/10.

Fig. 23-61 **Twin-Frame Screw Gear**. *(Illustration by Bruce Beveridge based on original drawing)*

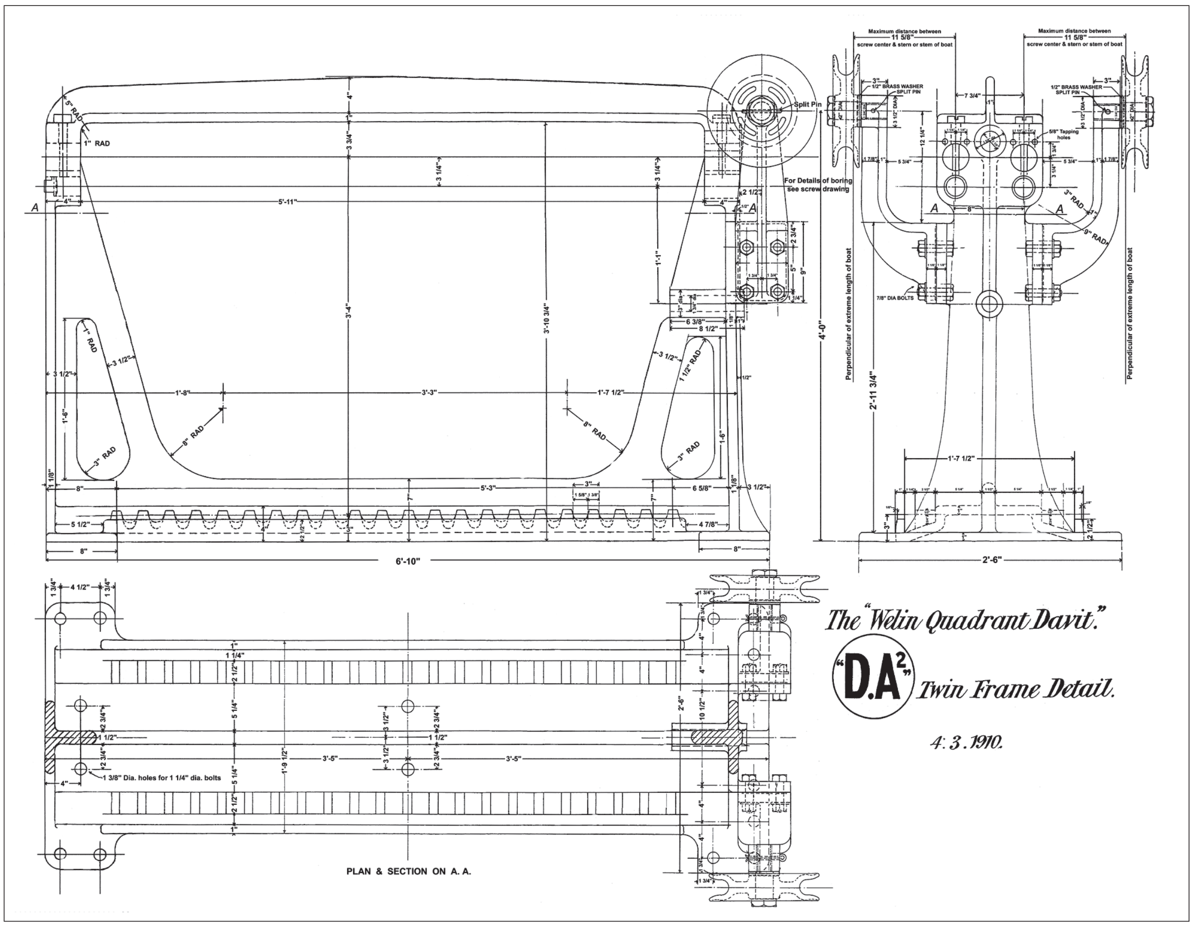

The "Welin Quadrant Davit."
"D.A²" Twin Frame Detail.
4. 3. 1910.
PLAN & SECTION ON A. A.
Maximum distance between 11 5/8" screw center & stern or stem of boat
Perpendicular of extreme length of boat
For Details of boring see screw drawing
Split Pin
1/2" BRASS WASHER
SPLIT PIN
7/8" DIA BOLTS
1 3/8" Dia. holes for 1 1/4" dia. bolts
6'-10"
5'-11"
4'-0"
2'-6"

Fig. 23-62 **Twin-Frame Detail**. *(Illustration by Bruce Beveridge based on original drawing)*

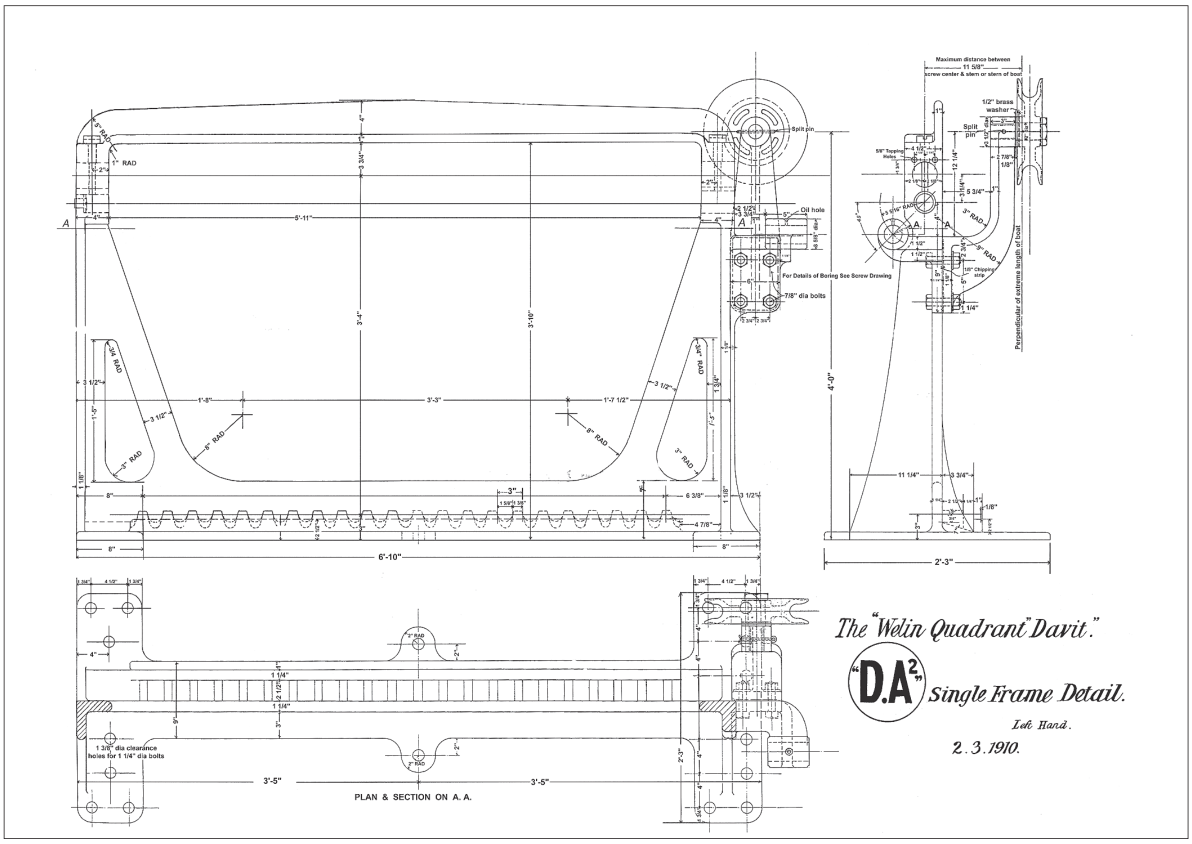

The "Welin Quadrant" Davit."
"D.A²" Single Frame Detail.
Left Hand.
2. 3. 1910.
PLAN & SECTION ON A. A.
Maximum distance between 11 5/8" screw center & stern or stem of boat
Perpendicular of extreme length of boat
For Details of Boring See Screw Drawing
Oil hole
Split pin
1/2" brass washer
5/8" Tapping Holes
7/8" dia bolts
1 3/8" dia clearance holes for 1 1/4" dia bolts
6'-10"
5'-11"
4'-0"
2'-3"

Fig. 23-63 **Single-Frame Detail**. *(Illustration by Bruce Beveridge based on original drawing)*

> *a deliberate policy that, when the subdivision of a vessel into watertight compartments exceeds what is considered necessary to ensure that she shall remain afloat after the worst conceivable accident, the need for lifeboats practically ceases to exist, and consequently a large number may be dispensed with. The fact that four or five compartments were torn open in Titanic, although no longer an inconceivable accident, may be regarded as an occurrence too phenomenal to be used wisely as a precedent in deciding the design and equipment of all passenger vessels in the future.*

Davit blocks and falls

The davit blocks were double-roller for the cutters and treble-roller for the main lifeboats. The relative value of the threefold-purchase lowering system was that it required less power for manipulation. The falls were manila, and care was exercised to stretch them well before they were rove through the blocks, afterwards taking the turns out and making the necessary adjustment at the becket to ensure smooth working. The blocks were elm, with Lignum Vitae roller sheaves, had swivel eyes and were bound inside with iron. The falls were long enough to lower the boat to the water with safety when the vessel was light. The rules further indicated that the 'life-lines' fitted to the davits were to be long enough to reach the water when the vessel was light; the life-lines were the means by which the crewmen on deck would climb down to the boat after it was lowered. Additionally the rules specified that hooks were not to be attached to the lower tackle blocks.

Lifebuoys and Lifebelts

Lifebuoys

There were forty-eight solid white lifebuoys on *Titanic*, fitted with beckets. These were of the type approved by the Board of Trade, and were placed at various locations about the weather decks. However, the ship's name was not painted on them. Per regulations, at least one lifebuoy was intended for each lifeboat.

The diameter of an approved lifebuoy was not to be less than 30in and its inside diameter not less than 17in. They were also required to be either (a) made of solid cork capable of floating in water for at least twenty-four hours with 32lb of iron suspended from it or (b) made of another approved material capable of floating in water for at least twenty-four hours with 32lb of iron suspended from it, provided that it was not stuffed with rushes, cork or shavings, or loose material (including granulated cork), and that it did not require inflation before use. All lifebuoys were to be fitted with beckets securely seized to the ship's railings, and no less than two of the lifeboats were to be fitted with life-lines 15 fathoms in length.

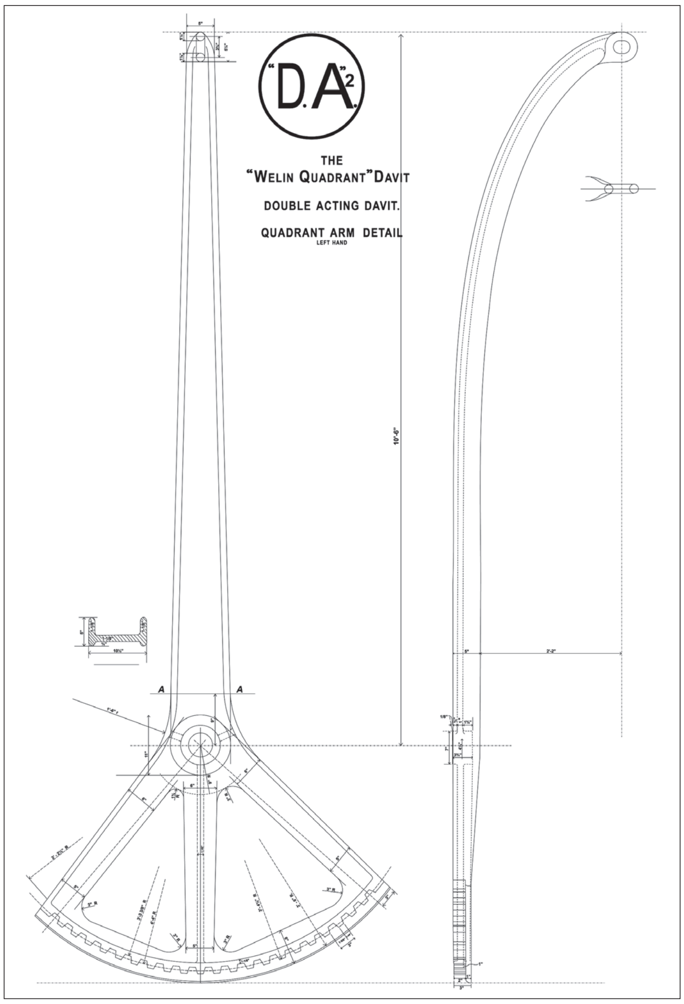


Fig. 23-64 **Davit Arms Detail**. *(Illustration by Bruce Beveridge based on original drawing)*

Titanic was provided with six 'Holmes Lights' for lifebuoys. These were devices attached to the lanyard that would go over with a lifebuoy in the instance of a man overboard. When the lifebuoy was thrown in the water, its weight removed a plug within a copper cylinder, igniting a light within one minute of reaching the water. This form of light was widely used in the English merchant service, although objection was sometimes made to the use of lights like the 'Holmes' on the grounds that the fumes given off were offensive and, in some cases, asphyxiating. Due to these objections, they were not connected rigidly to the buoy but attached to it by a short line which would let them float some distance from the person in the water. The lights were usually stowed in the area of the Bridge and individually sealed until needed. When needed, they were punched or torn open by a simple tool attached to it.

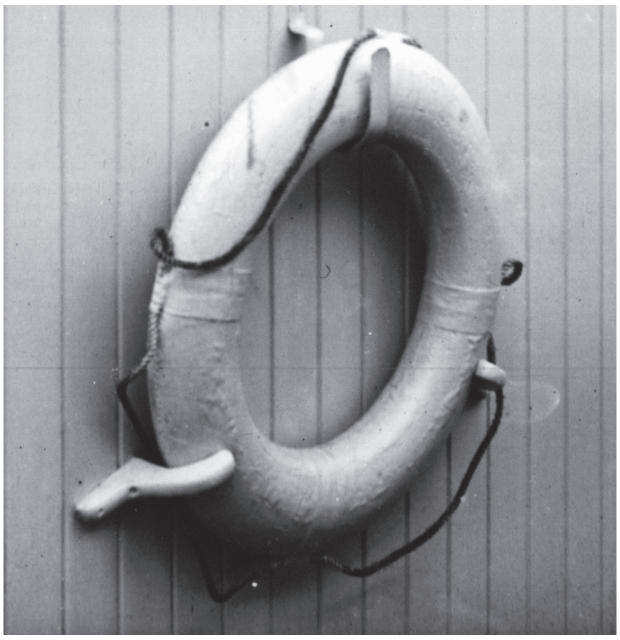


Fig. 23-65 **Lifebuoy on *Olympic* (1)** – This image, taken in March 1912, shows one of *Olympic*'s lifebuoys on the starboard Bridge wing bulwark. Note that the ship's name is not lettered on the lifebuoy. This is a feature that would not be seen on White Star ships until much later. Many fakes have been produced with *Titanic*'s name painted on the ring, and these occasionally turn up at auction to lure the unwary buyer. *(H&W/Authors' collection)*

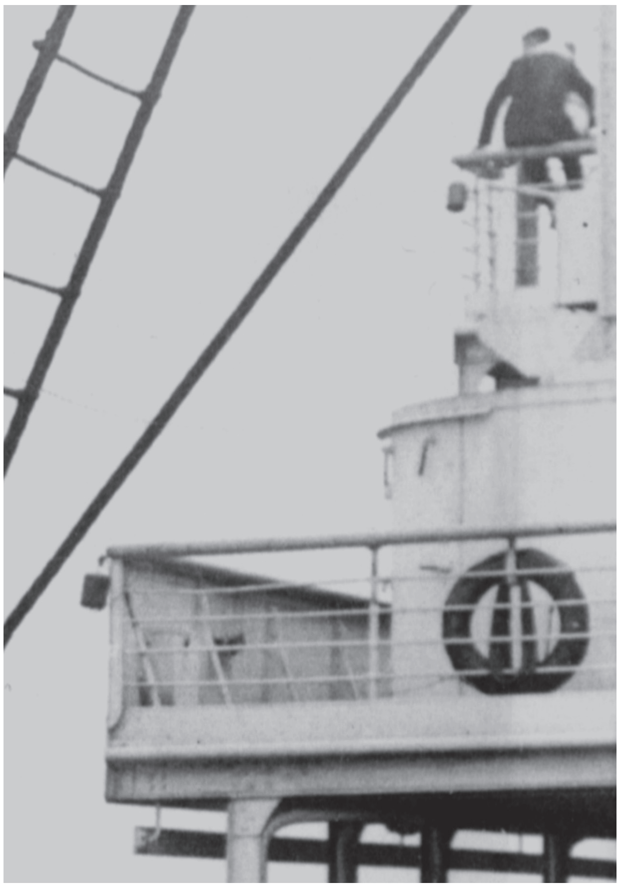


Fig. 23-67 **Lifebuoy on *Olympic* (2)** – In this image of *Olympic*'s A Deck on the port side aft, a lifebuoy can be seen with an attached Holmes Light. A Holmes Light is also visible on the railings of the Boat Deck above, next to the man who is foolishly sitting on the rail. When this picture was taken in the early 1920s the color of the lifebuoy had changed, but the requirement of an attached light had not. Also, note the container with the rounded top against the inside of the bulwark – this held a fire hose, and the dark object seen to the right of it is a deck hydrant.

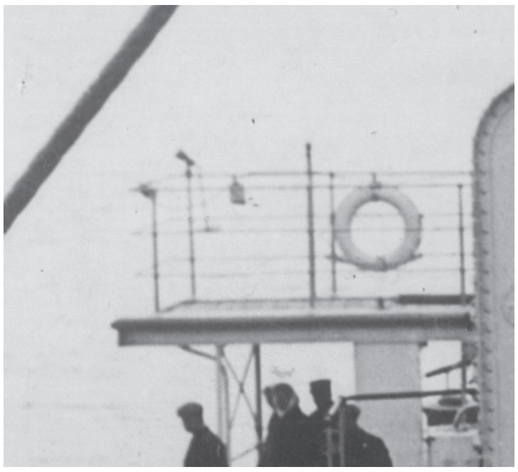
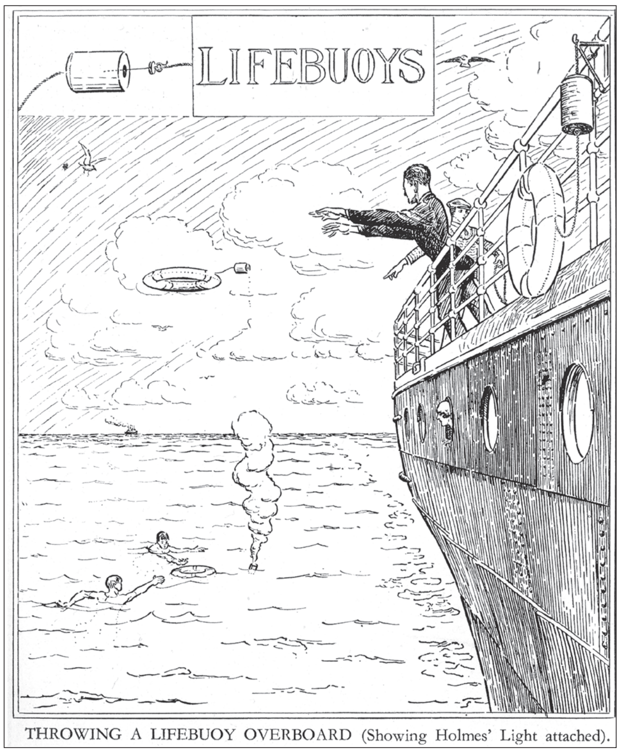


Fig. 23-66 **Lifebuoy on *Titanic*** – This enlarged image of the starboard side of *Titanic*'s Docking Bridge shows a lifebuoy mounted on the railings. The other objects seen against the railings are, from left to right, a Walker's Cherub log, a Holmes Light canister, a speaking tube, and the lifebuoy. (The speaking tube may have been used to communicate during docking with the steering engine space below; this space also contained the capstan engines and several mooring bitts.)



THROWING A LIFEBUOY OVERBOARD (Showing Holmes' Light attached).

Fig. 23-68 **Holmes Light Illustration** – Holmes Lights were intended to mark the position of a man overboard at night.

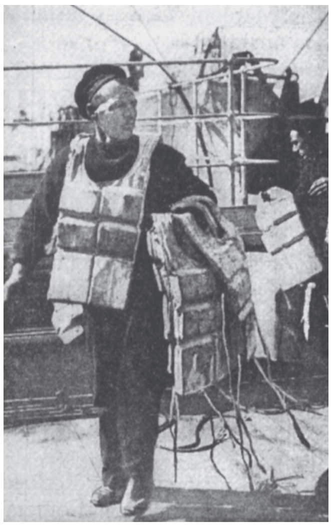


Fig. 23-69 **Deckhand with Lifejackets** – After *Titanic* sank, there was an inspection of *Olympic*'s lifesaving appliances and the addition of extra boats. This image depicts a crewman on the deck of *Olympic* with lifejackets to be handed out during the morning drill. *(*The Daily Sketch*/Ray Lepien collection)*

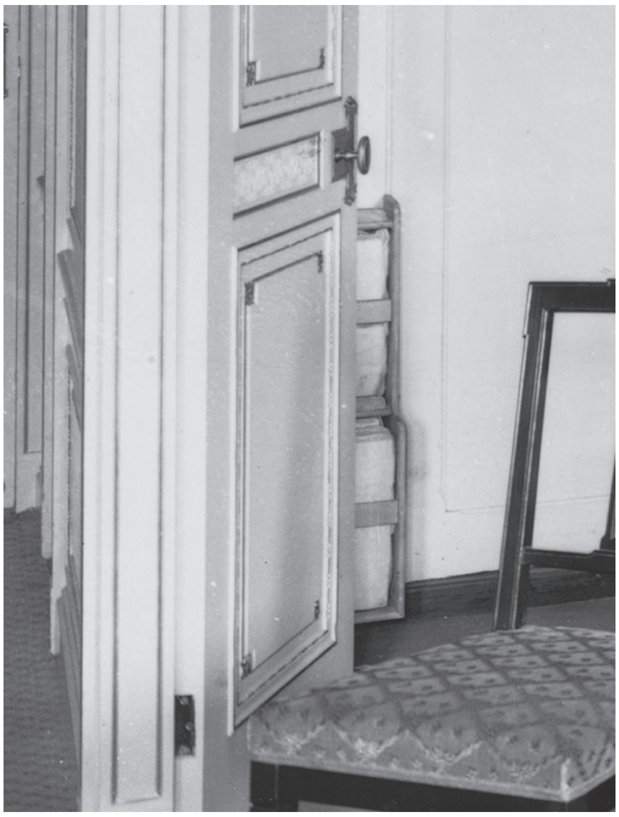
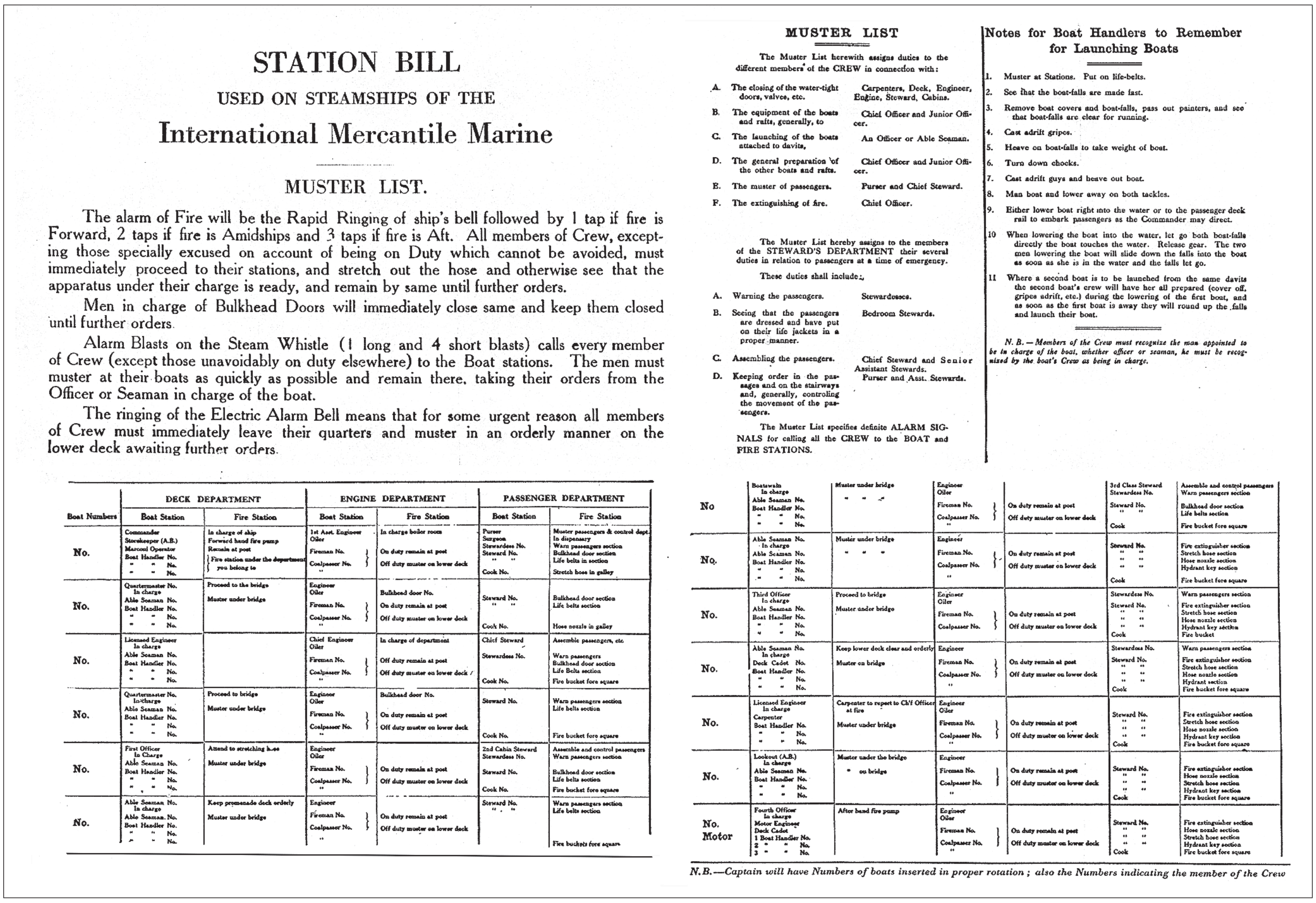


Fig. 23-70 **Life Belts Stowed** – This image of stateroom B58 on *Titanic* shows several lifebelts stowed in a rack within the wardrobe closet. In addition to stowage in wardrobe closets, lifebelts were stowed in numerous places for easy access, such as racks mounted to the deck head and, in Third Class, within lockers along the alleyways. There was no issue with the number of life belts on *Titanic*, as is well documented. *(Daniel Klistorner collection)*



STATION BILL

USED ON STEAMSHIPS OF THE

International Mercantile Marine

MUSTER LIST.

The alarm of Fire will be the Rapid Ringing of ship's bell followed by 1 tap if fire is Forward, 2 taps if fire is Amidships and 3 taps if fire is Aft. All members of Crew, excepting those specially excused on account of being on Duty which cannot be avoided, must immediately proceed to their stations, and stretch out the hose and otherwise see that the apparatus under their charge is ready, and remain by same until further orders.

Men in charge of Bulkhead Doors will immediately close same and keep them closed until further orders.

Alarm Blasts on the Steam Whistle (1 long and 4 short blasts) calls every member of Crew (except those unavoidably on duty elsewhere) to the Boat stations. The men must muster at their boats as quickly as possible and remain there, taking their orders from the Officer or Seaman in charge of the boat.

The ringing of the Electric Alarm Bell means that for some urgent reason all members of Crew must immediately leave their quarters and muster in an orderly manner on the lower deck awaiting further orders.

MUSTER LIST

The Muster List herewith assigns duties to the different members of the CREW in connection with:

A.	The closing of the water-tight doors, valves, etc.	Carpenters, Deck, Engineer, Engine, Steward, Cabins.
B.	The equipment of the boats and rafts, generally, to	Chief Officer and Junior Officer.
C.	The launching of the boats attached to davits,	An Officer or Able Seaman.
D.	The general preparation of the other boats and rafts.	Chief Officer and Junior Officer.
E.	The muster of passengers.	Purser and Chief Steward.
F.	The extinguishing of fire.	Chief Officer.

The Muster List hereby assigns to the members of the STEWARD'S DEPARTMENT their several duties in relation to passengers at a time of emergency.

These duties shall include:

A.	Warning the passengers.	Stewardesses.
B.	Seeing that the passengers are dressed and have put on their life jackets in a proper manner.	Bedroom Stewards.
C.	Assembling the passengers.	Chief Steward and Senior Assistant Stewards.
D.	Keeping order in the passages and on the stairways and, generally, controling the movement of the passengers.	Purser and Asst. Stewards.

The Muster List specifies definite ALARM SIGNALS for calling all the CREW to the BOAT and FIRE STATIONS.

Notes for Boat Handlers to Remember for Launching Boats

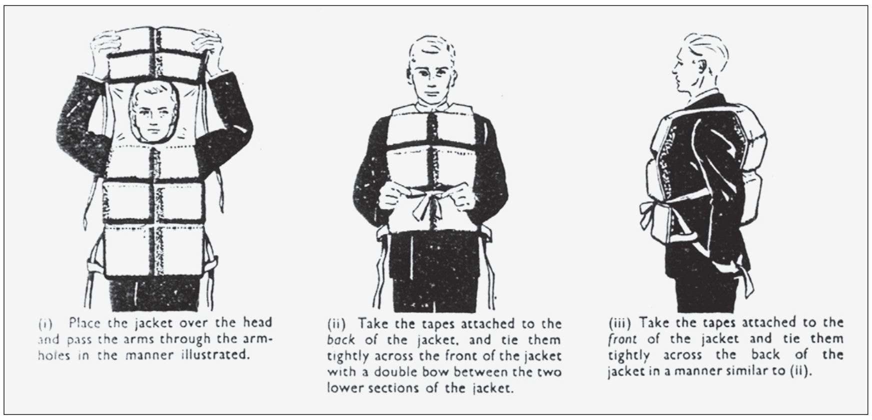
1. Muster at Stations. Put on life-belts.
2. See that the boat-falls are made fast.
3. Remove boat covers and boat-falls, pass out painters, and see that boat-falls are clear for running.
4. Cast adrift gripes.
5. Heave on boat-falls to take weight of boat.
6. Turn down chocks.
7. Cast adrift guys and heave out boat.
8. Man boat and lower away on both tackles.
9. Either lower boat right into the water or to the passenger deck rail to embark passengers as the Commander may direct.
10. When lowering the boat into the water, let go both boat-falls directly the boat touches the water. Release gear. The two men lowering the boat will slide down the falls into the boat as soon as she is in the water and the falls let go.
11. Where a second boat is to be launched from the same davits the second boat's crew will have her all prepared (cover off, gripes adrift, etc.) during the lowering of the first boat, and as soon as the first boat is away they will round up the falls and launch their boat.

N. B.—Members of the Crew must recognize the man appointed to be in charge of the boat, whether officer or seaman, he must be recognized by the boat's Crew as being in charge.

Boat Numbers	DECK DEPARTMENT		ENGINE DEPARTMENT		PASSENGER DEPARTMENT	
	Boat Station	Fire Station	Boat Station	Fire Station	Boat Station	Fire Station
No.	Commander Storekeeper (A.B.) Marconi Operator Boat Handler No. " " No. " " No.	In charge of ship Forward hand fire pump Remain at post Fire station under the department you belong to	1st Asst. Engineer Oiler Fireman No. Coalpasser No. "	In charge boiler room On duty remain at post Off duty muster on lower deck	Purser Surgeon Stewardess No. Steward No. " " Cook No.	Muster passengers & control dept. In dispensary Warn passengers section Bulkhead door section Life belts in section Stretch hose in galley
No.	Quartermaster No. In charge Able Seaman No. Boat Handler No. " " No. " " No.	Proceed to the bridge Muster under bridge	Engineer Oiler Fireman No. Coalpasser No. "	Bulkhead door No. On duty remain at post Off duty muster on lower deck	Steward No. " " Cook No.	Bulkhead door section Life belts section Hose nozzle in galley
No.	Licensed Engineer In charge Able Seaman No. Boat Handler No. " " No. " " No.		Chief Engineer Oiler Fireman No. Coalpasser No. "	In charge of department Off duty remain at post Off duty muster on lower deck	Chief Steward Stewardess No. Cook No.	Assemble passengers, etc. Warn passengers Bulkhead door section Life Belts section Fire bucket fore square
No.	Quartermaster No. In charge Able Seaman No. Boat Handler No. " " No. " " No.	Proceed to bridge Muster under bridge	Engineer Oiler Fireman No. Coalpasser No. "	Bulkhead door No. On duty remain at post Off duty muster on lower deck	Steward No. Cook No.	Warn passengers section Life belts section Fire bucket fore square
No.	First Officer In Charge Able Seaman No. Boat Handler No. " " No. " " No.	Attend to stretching hose Muster under bridge	Engineer Oiler Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	2nd Cabin Steward Stewardess No. Steward No. Cook No.	Assemble and control passengers Warn passengers section Bulkhead door section Life belts section Fire bucket fore square
No.	Able Seaman No. In charge Able Seaman. No. Boat Handler No. " " No. " " No.	Keep promenade deck orderly Muster under bridge	Engineer Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	Steward No. " "	Warn passengers section Life belts section Fire buckets fore square
No	Boatswain In charge Able Seaman No. Boat Handler No. " " No. " " No.	Muster under bridge " " "	Engineer Oiler Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	3rd Class Steward Stewardess No. Steward No. " " Cook	Assemble and control passengers Warn passengers section Bulkhead door section Life belts section Fire bucket fore square
No.	Able Seaman No. In charge Able Seaman No. Boat Handler No. " " No. " " No.	Muster under bridge " " "	Engineer Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	Steward No. " " " " " " Cook	Fire extinguisher section Stretch hose section Hose nozzle section Hydrant key section Fire bucket fore square
No.	Third Officer In charge Able Seaman No. Boat Handler No. " " No. " " No.	Proceed to bridge Muster under bridge	Engineer Oiler Fireman No. Coalpasser No.	On duty remain at post Off duty muster on lower deck	Stewardess No. Steward No. " " " " " " Cook	Warn passengers section Fire extinguisher section Stretch hose section Hose nozzle section Hydrant key section Fire bucket
No.	Able Seaman No. In charge Deck Cadet No. Boat Handler No. " " No. " " No.	Keep lower deck clear and orderly Muster on bridge	Engineer Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	Stewardess No. Steward No. " " " " " " Cook	Warn passengers section Fire extinguisher section Stretch hose section Hose nozzle section Hydrant section Fire bucket fore square
No.	Licensed Engineer In charge Carpenter Boat Handler No. " " No. " " No.	Carpenter to report to Ch'f Officer at fire Muster under bridge	Engineer Oiler Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	Steward No. " " " " " " Cook	Fire extinguisher section Stretch hose section Hose nozzle section Hydrant key section Fire bucket fore square
No.	Lookout (A.B.) In charge Able Seaman No. Boat Handler No. " " No. " " No.	Muster under the bridge " on bridge	Engineer Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	Steward No. " " " " " " Cook	Fire extinguisher section Hose nozzle section Stretch hose section Hydrant key section Fire bucket fore square
No. Motor	Fourth Officer In charge Motor Engineer Deck Cadet 1 Boat Handler No. 2 " " No. 3 " " No.	After hand fire pump	Engineer Oiler Fireman No. Coalpasser No. "	On duty remain at post Off duty muster on lower deck	Steward No. " " " " " " Cook	Fire extinguisher section Hose nozzle section Stretch hose section Hydrant key section Fire bucket fore square

N.B.—Captain will have Numbers of boats inserted in proper rotation; also the Numbers indicating the member of the Crew

Fig. 23-71 **Ship's Muster List** – The crew of *Titanic* were assigned boat and fire stations. Though this example from an International Mercantile Marine ship is from the 1920s, a list much like this would have been posted on *Titanic* in plain view in the crew areas. This issue was inquired about quite extensively during the British Board of Trade hearings after the sinking.



(i) Place the jacket over the head and pass the arms through the armholes in the manner illustrated.

(ii) Take the tapes attached to the *back* of the jacket, and tie them tightly across the front of the jacket with a double bow between the two lower sections of the jacket.

(iii) Take the tapes attached to the *front* of the jacket and tie them tightly across the back of the jacket in a manner similar to (ii).

Fig. 23-72 **Illustration of a Lifejacket** – A typical cork-and-canvas lifejacket of English manufacture, very similar to that used on *Titanic.*

Lifebelts

3,560 lifebelts of the latest improved overhead pattern approved by the Board of Trade were placed on board the vessel by Fosberry & Co. of London and distributed throughout the sleeping accommodations. In some Third Class areas the belts could also be found in metal lockers located in the alleyways.

All lifebelts were to be placed so as to be readily accessible to all persons on board. An approved lifebelt was a device which did not require inflation before use and which was capable of floating in the water for twenty-four hours with 15lb of iron suspended from it.

Notes

1. *Titanic*'s crew did not refer to these as lifeboats, and did not consider them to be boats. They referred to them as rafts in most cases.
2. Much of the information in this section requires a knowledge of wooden boat construction and involves a great deal of nautical terminology that may be unfamiliar to the reader. As the number of terms used precludes an explanation of each individually, they have been included in the Glossary which appears at the end of both volumes. Readers wishing to skip this section should turn to page 568 and resume reading at the section entitled 'Lowering Gear'.
3. The Board of Trade ship surveyor, Francis Carruthers, wrote that the Section D emergency cutters had only four thwarts. This may have been because there were no head and sternsheets and the extreme end seats were not considered thwarts in the proper sense of the term.
4. As related by survivors, the Murray's Disengaging Gear failed to release in some cases, resulting in a crewman or passengers having to utilize a knife to cut the falls free from the hooks. This problem, however, may have had more to do with the inexperience of the crewman than a malfunction of the device.
5. The Board of Trade surveyor found that the freeboard light of these boats, without equipment, was 3ft 6in. The freeboard with sixty-six men and four oars was 2ft 3in. Estimated freeboard with sixty-six men and full equipment on board was not less then 2ft 0in.
6. In numerical analysis, Simpson's Rule is a method for numerical integration, the numerical approximation of definite integrals. Simpson's Rule was used to prove Stirling's formula which was used to approximate the capacity of the lifeboats.
7. Colza oil is a non-odorous, non-drying oil made from the seeds of the Field Mustard plant. In 1912 it was used extensively as a machinery lubricant and as a lamp oil.
8. 'Reefing' refers to the process of shortening a sail in heavy weather by gathering up and securing part of the sail to reduce its overall size.
9. This list of equipment was what remained at the time of inventory. Some items in the lifeboats had been dumped overboard by *Titanic*'s crew to make room for passengers, and some of it was also looted from the boats by souvenir hunters while the boats were on *Carpathia* and at the docks.
10. It must be remembered that the crewmen on deck could not see the lifeboat as it was being lowered, and had to rely on the directions from an officer looking overboard. From this viewpoint (looking directly downward) it was not easy to see if one end of the boat was dropping more rapidly than the other, especially at night.

Chapter 24

The Marconi Apparatus

Titanic's wireless equipment was among the most powerful in the world at the time, capable of communicating with stations several hundred or even a thousand miles away. Wireless communication was still relatively new in 1912, the first transatlantic signal having been sent only ten-and-a-half years earlier between Cornwall, Great Britain, and St. John's, Newfoundland, on the North American coast. However, by the time *Titanic* was launched all the major Atlantic liners were equipped with wireless apparatus. All this was the brainchild of Guglielmo Marconi, whose pioneering experiments made possible the sending of wireless messages aboard ship as easy and convenient as sending a telegram on land.

Passengers on *Titanic* wishing to send a telegram would proceed to the ship's Enquiry Office, located on the starboard side of C Deck by the First Class grand staircase. Messages were handwritten and paid for at a cost of 12*s 6d* for the first ten words, and 9*d* for each additional word (traveling westbound). The address and signature was free of charge. The message would be sent from the Enquiry Office via pneumatic tube to the Marconi Operating Room on the Boat Deck. The Marconi operator would count the words and keep a tally to be balanced with the Purser's Office at the end of the day. Incoming messages would be handwritten by the Marconi receiving operator, then typed out by the relief operator and sent via pneumatic tube to the Enquiry Office where it would be delivered to the passenger by a Bellboy.

The use of wireless was not limited to personal communication, but also extended to transmittal of the news to ships at sea. In 1912, an ocean voyage no longer meant time at sea in complete isolation from the rest of the world – passengers could even wake up to a morning newspaper, albeit somewhat abbreviated. The *Atlantic Daily Bulletin* was a paper printed aboard *Titanic* and other White Star Line ships thanks to wireless at sea; it carried columns of news from the world's centers, and the latest important Stock Exchange quotations from London, Paris and New York, all transmitted to the ship by wireless telegraphy. All ships carrying wireless in the North Atlantic trade were either in direct communication with shore stations or with vessels which could speak to the shore. For some hours during the night[1] the wireless operator would receive messages for publication the following morning and usually took down about 600 words. The messages were prepared by a special news department in connection with the Marconi company.[2] Besides being a telegraphist, the operator had to know something of public affairs, and also be able to act as a journalist to the extent that he might have had to sub-edit the telegrams in preparation for the following morning's paper.

The Marconi wireless instruments of the time were made in a secluded part of a quiet Essex town, in the premises of a disused soap factory. The Marconi company published a house magazine called the *Marconigraph* and in an article printed in the May 1912 issue, *Titanic*'s installation was addressed. A partial excerpt follows:

> *The wireless equipment of the 'Titanic' was the most powerful possessed by any vessel of the mercantile marine and only equaled by that of the 'Olympic'. Its generating plant consisted of a 5-kW motor-generator set, yielding current at 300 volts 60 cycles. The motor of the set was fed at 100 volts DC from the ship's lighting circuit, normally supplied from steam-driven sets. The alternator of the motor-generator set was connected to the primary of an air-core transformer and the condenser consisted of oil-immersed glass plates. To eliminate as far as possible the spark gap and its consequent resistance, which, as is well known, is the principle cause of the damping of the waves in the transmitting circuit, the ordinary Marconi disc discharger was used. This is driven off the shaft of the motor-generator. The guaranteed working range of the equipment was 250 miles under any atmospheric conditions, but actually communication could be kept up to about 400 miles, while at night the range was often increased to about 2,000 miles. The aerial was supported by the two masts, 200ft. high, stepped 600ft. apart and had a mean height of 170ft. It was of the twin T type and was used for the double purpose of transmitting and receiving. The earth*

> *connection was made by insulated cable to convenient points on the hull of the vessel.*
>
> *The receiver was the Marconi standard traveling band, or magnetic detector, used in conjunction with their multiple tuner, providing for reception of all waves between 100 and 2,500 meters. The multiple tuner was calibrated to permit of the instrument being set to any pre-arranged wavelength and further to be provided with a change switch to permit of instantaneous change of circuit from a highly-synchronized, tuned condition to an untuned condition (for stand-by), especially devised for picking up incoming signals of widely different wave-lengths. By reason of its robust nature the magnetic detector could be employed permanently connected to the transmitting aerial, thus dispending with all mechanical change-over switching arrangements.*

Technology in the field of wireless telegraphy was advancing rapidly during the period between its inception at the close of the nineteenth century and the beginning of the second decade of the twentieth century. When *Olympic* was in the early stages of construction, the famous publication *The Shipbuilder* reported that she would be outfitted with a 1½kW Marconi system. This can be confirmed by early rigging plans which show one set of 'twin-T' aerial wires typical of 1½kW installations of the time. Sometime during the latter period of her fitting-out, she was retro-fitted with a standard 5kW system. Contemporary references state that the arrangements of the circuits in the 1½ and 5kW power sets were very much the same, the real differences only consisting of modifications in the various pieces of apparatus. Both transmitted on the standard commercial marine frequencies of 300 and 600 meters. Marconi had supplied the Admiralty with his equipment since 1903, and with his 5kW sets in warships there was usually an upgraded model installed. The main difference between the 'battleship set' and the commercial set was that the former was fitted with eight instead of four condensers. These upgraded sets were capable of transmitting on wavelengths of 1,200 meters.

One of the problems with radio apparatus of *Titanic*'s era was its limited selectivity in tuning. The result of this was 'jamming' between the various operators transmitting over wide frequency ranges. The transmitting equipment could be tuned, so to speak, and the tuners were designed to cut out much of the unwanted transmissions, however 'bleed-over' still took place because of the damped waves produced by the spark transmitters. The spark sets were made obsolete in the 1920s by valve technology.

WIRELESS ACCOMMODATIONS

Olympic's wireless accommodations were originally located along the port side of the Officers' Quarters deckhouse. On *Titanic,* however, the wireless accommodations took up the mid-section of the deckhouse, just forward of the Elevator Machinery Room. This change in location was part of a redesign of the Officers' Quarters deckhouse, which was extended forward approximately 9ft to provide space for a number of First Class staterooms within the after end of the structure. During *Olympic*'s December 1912 refit, the Officers' Quarters deckhouse and Marconi accommodations were modified to match those of her younger sister.

With *Titanic*'s Marconi suite located centrally, there was more room available for the three interconnected compartments. On the starboard side was the cabin for the two Marconi operators,[3] with mahogany bunks and cabinetry. The middle compartment was the Operating Room. The main operating table, which held the Morse key, was located against the after bulkhead. The port side compartment was the 'Silent Room'. The Silent Room was essentially a 'room inside of a room' designed to muffle the sound of the rotary spark disc. The sound-deadening was very effective; the spark disc itself was housed within a teak case and the room was heavily insulated so that both the operators and those occupying the nearby staterooms remained undisturbed by the din of the machinery.

Although there was a telephone connection to the ship's central exchange, there was no telephone connection with the Navigating Bridge; in fact, the only way to relay an incoming message to the Officer of the Watch was to hand-deliver it. Following *Titanic*'s sinking, however, a speaking tube would be installed on *Olympic* and *Britannic* between the Bridge and the Marconi Operating Room.

By far, the greatest use of the wireless on *Titanic* was by the passengers. Unlike ships of today, the Marconi apparatus was not considered integral to the ship's operation. Nonetheless, *Titanic* was able to maintain a twenty-four-hour wireless watch between the two operators, and they did endeavor to deliver messages to the Bridge as soon as they could. 'Bridge-to-Bridge' traffic did not, however, take precedence over passenger 'Marconigrams', and operators were under no obligation to deliver them immediately upon receipt. Although *Titanic*'s operators signed ship's articles and drew pay from the White Star Line, this was secondary to their employment with the Marconi company.[4]

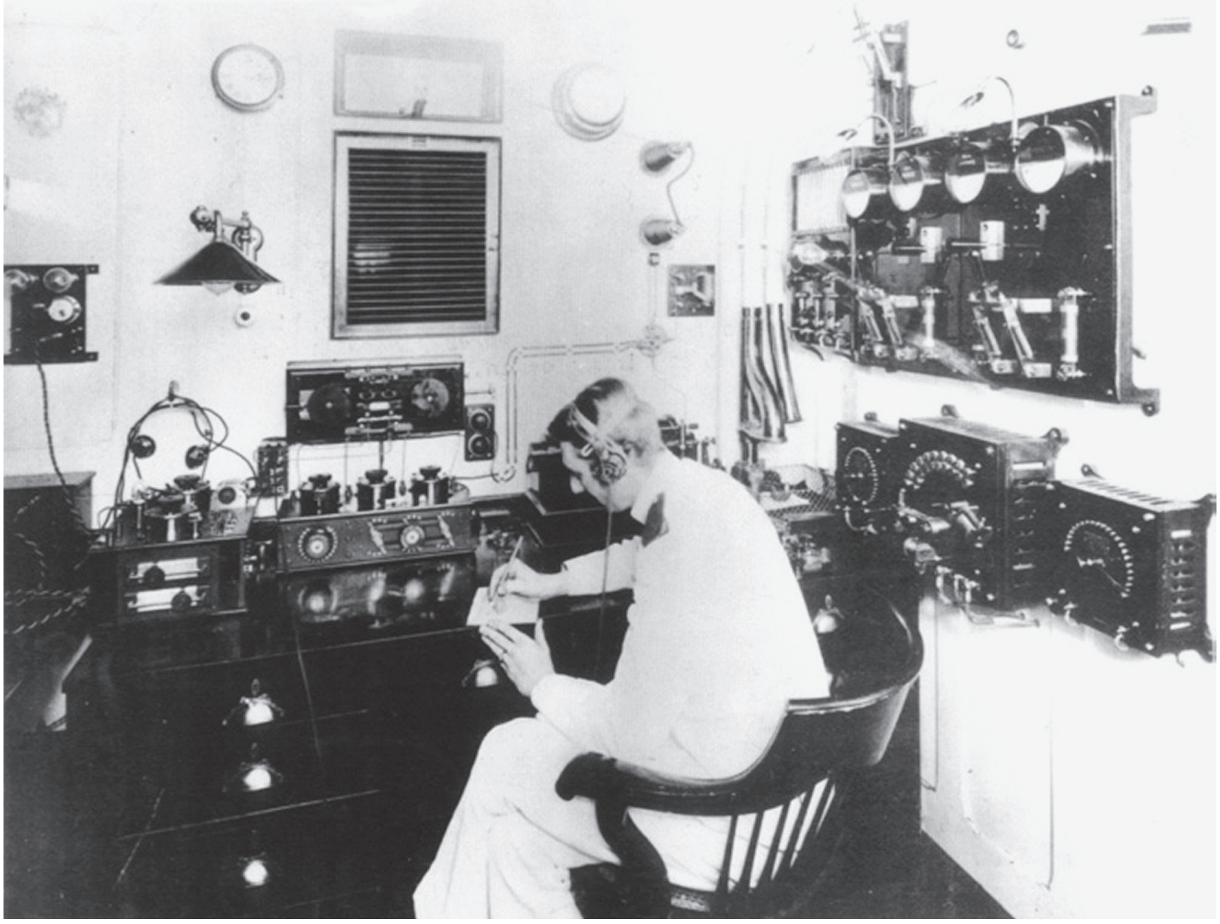


Fig. 24-1 **Marconi Operating Room on *Olympic*** – The original location of the Marconi Operating Room on *Olympic* in 1911 was on the port side of the Officers' Quarters deckhouse. This room would be moved after *Olympic*'s 1912-13 refit.

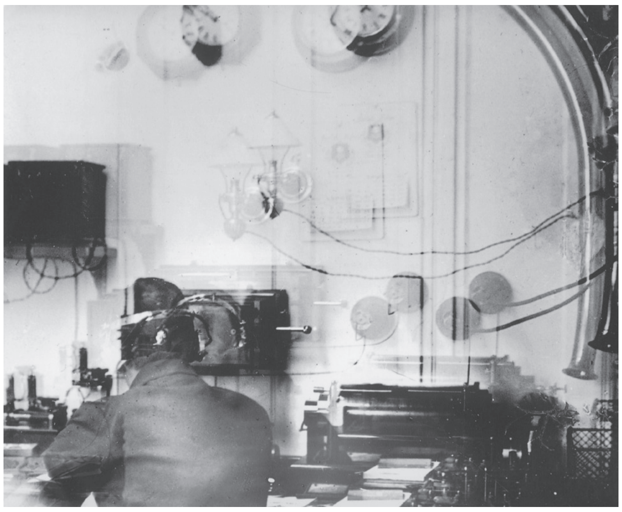
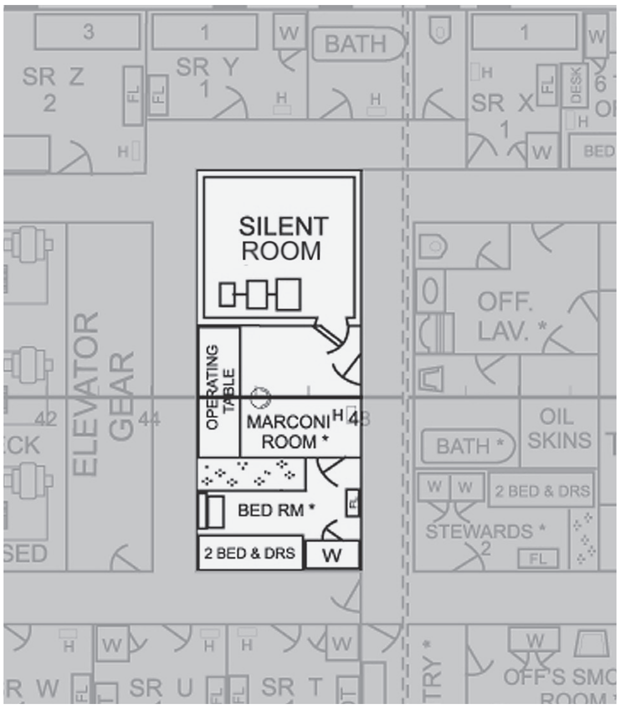


Fig. 24-2 ***Titanic*'s Marconi Operating Room** – The only known picture of *Titanic*'s Marconi Operating Room, with one of the two operators at the desk. This image is a double exposure, but is priceless due to its rarity. The two clocks mounted on the bulkhead indicate the time at the place of destination and the local time aboard the ship. *(Father Browne photograph/Authors' collection)*


3
1
W
BATH
1
W
SR Z
2
FL
FL
SR Y
1
H
H
H
SR X
1
FL
DESK
6
H
W
BED
H
SILENT
ROOM
ELEVATOR
GEAR
OFF.
LAV. *
OPERATING
TABLE
42
44
MARCONI
ROOM *
H
48
BATH *
OIL
SKINS
BED RM *
W
W
2 BED & DRS
STEWARDS *
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FL
2 BED & DRS
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SED
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FL
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TRY *
OFF'S SMO
ROOM

Fig. 24-3 **Plan of *Titanic*'s Marconi Suite**. *(Illustration by Bruce Beveridge)*

GUGLIELMO MARCONI

An early pioneer in wireless telegraphy was Sir William Preece, chief engineer of the British Post Office. The work of Preece, important though it was, did not attract the attention of the public to the extent that might have been expected. This was due to the fact that no sooner had he demonstrated wireless telegraphy to be a commercial possibility than his system was practically superseded by another which was brought to England by Signor Guglielmo Marconi in 1896. The possibilities of Marconi's system were at once recognized by Preece, so it is true in saying that the Engineering Department of the British Post Office deserved the credit for giving "æther-wave" telegraphy the boost which brought it to a viable state and hence into the future.

To Guglielmo Marconi, however, belongs the honor of having devised the first practical wireless telegraph system. In the patent specifications filed at the Patent Office by Marconi in 1896, he stated that as a result of his invention, electrical action could be transmitted through earth, air, or water by means of oscillations of high frequency. Sadly, Marconi spent much of his time in court defending his patents or protecting them. It was said by Marconi's detractors that *"there is nothing novel in the Marconi system."* To a certain extent this was true. The history of wireless telegraphy plainly illustrates that it was the work, not of one man, but of many who managed to narrowly miss the honor destined for Marconi. Professor James Clerk Maxwell developed the theory and foretold the behavior of the electromagnetic waves. Heinrich Hertz produced, demonstrated and described them. Augusto Righi designed and improved a form of oscillator while Edouard Branly rediscovered the principle of the coherer (receiving device) and produced a practical form of the instrument. Sir Oliver Lodge had shown his wireless apparatus and, in 1894, succeeded in "signaling through space without wires." Captain Henry Jackson succeeded in sending messages between Admiralty ships in 1895, but for some reason, probably owing to his official position, his results were not publicly advertised.

Nevertheless, the merit of the first practical system was awarded to Marconi. As Sir William Preece put it, *'We all knew about the egg, but Marconi showed us how to make it stand on end.'*

There was a strong fraternity among wireless operators on the Atlantic, even though they did not necessarily know each other. They generally considered themselves to be part of an elite group, and aboard ship enjoyed a status equivalent to that of a Junior Officer. Wireless Telegraphists employed by the Marconi company had to undergo considerable training prior to assignment aboard ship; they were expected not only to possess a complete working knowledge of the entire apparatus, but to be able to troubleshoot and repair it as necessary.

Pneumatic tubes

The pneumatic tubes conveying messages to and from the Enquiry Office were the 'Rebesi' type made by Reid Brothers, Engineers Ltd of London. The tubes were run alongside bulkheads and underneath decks between the two offices, and the telegram forms filled out by passengers (or the telegrams received by the ship) were conveyed along these tubes by air pressure with a transit time of about five seconds. Motive power was derived from an electric motor direct coupled to a 'Rebesi' machine which created a continuous vacuum in the tubes. The machinery was placed in the Elevator Machinery Room immediately above the elevator shafts, and an air main was run from this room to the Marconi Operating Room to supply the tubes. An exhaust main was also fitted from the lift head to one of the funnels. 'Up' and 'down' tubes were provided so that the messages could travel both ways simultaneously and, beyond inserting the carrier in the tube, the action was entirely automatic.

When a carrier was inserted in the tube, it was taken away by the air current and discharged automatically on the desk at the distant end. The apparatus which accomplished this was constructed so that the air current was taken around a by-pass, thus preventing any interruption of the air supply while the carrier was guided through the door and out of the tube. The whole of the plant was simple, virtually trouble-free and it required only ½BHP to work the entire installation.

Continental Morse code and station identification

Prior to the London Radiotelegraphic Convention of July 1, 1913, United States commercial shore stations and US coasting vessels used American Morse code. All foreign stations – ship and shore, public and private – used Continental Morse. The American Morse was thought to be faster; the Continental Morse was a dash and a dot code with a maximum of four elements in any letter. The American Morse used five elements in the letter P, four elements and a space in Y, Z and '&', and a long dash for the letter L. Fifteen of the twenty-six letters of the alphabet were the same in both codes. An experienced operator could send twenty-five words per minute or more.

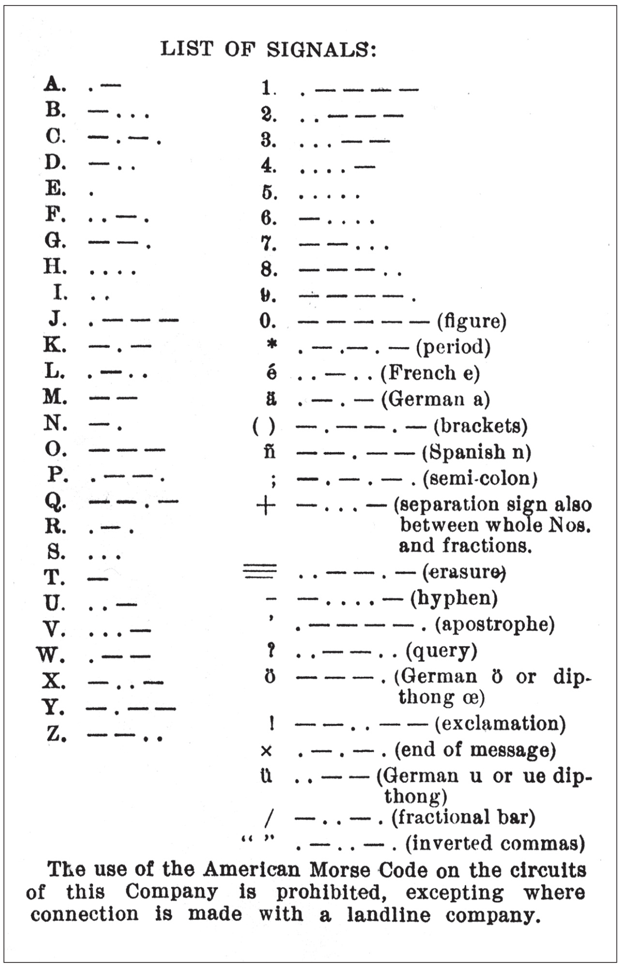
'CQD', although a Marconi distress code, was recognized among operators from competing wireless companies. During the International Wireless Telegraph Conference at Berlin in 1906, it was decided to use 'SOS' as the standard signal for distress. This was to be implemented with the elements contained in the Continental Morse language – three dots, three dashes, three dots. However, when Phillips sent his distress signals following *Titanic*'s collision with the iceberg, he used 'CQD' every time he sent a distress call, except for one time only when he switched to 'SOS'.[5]

Both ship and shore stations were identified by three-letter call signs. These were assigned by the wireless companies themselves at the time; the majority began with 'M' since the Marconi company was the supplier for the overwhelming majority of users. *Titanic*'s call sign was MGY; the call signs for some of the more well-known ships involved with the events of April 14–15, 1912, were MPA (*Carpathia*); MWL (*Californian*); and MKC (*Olympic*). Cape Race, Newfoundland, was MCE.

THE AERIAL AND FITTINGS

Titanic's aerial served the double purpose of both radiating and receiving the electric waves. It took the form of two 'twin-T' aerials, a common configuration aboard commercial and naval vessels using 5kW power sets. The 'T' designation was based on its appearance and the point to which the lead-ins connected to the horizontal wires. When looking at the ship's profile, the horizontal wires of the aerials formed the flat top of the letter T. The down-leads, which connected to the mid-section of the aerials, formed the vertical base of the T and were equal in conductivity to the horizontal wires. Each set of aerials was in parallel by virtue of their installation. A similar aerial design was called the 'inverted-L'. This configuration differed in that the down-leads were attached to one end of the horizontal antenna span.

The fundamental wavelength of the 'T' aerial was invariably less than that of the inverted-L type of the same dimensions. The 'L' type was preferred in ship



LIST OF SIGNALS:

A. . —
B. — . . .
C. — . — .
D. — . .
E. .
F. . . — .
G. — — .
H. . . . .
I. . .
J. . — — —
K. — . —
L. . — . .
M. — —
N. — .
O. — — —
P. . — — .
Q. — — . —
R. . — .
S. . . .
T. —
U. . . —
V. . . . —
W. . — —
X. — . . —
Y. — . — —
Z. — — . .

1. . — — — —
2. . . — — —
3. . . . — —
4. . . . . —
5. . . . . .
6. — . . . .
7. — — . . .
8. — — — . .
9. — — — — .
0. — — — — — (figure)
* . — . — . — (period)
é . . — . . (French e)
ä . — . — (German a)
( ) — . — — . — (brackets)
ñ — — . — — (Spanish n)
; — . — . — . (semi-colon)
+ — . . . — (separation sign also between whole Nos. and fractions.
≡ . . — — . — (erasure)
- — . . . . — (hyphen)
' . — — — — . (apostrophe)
? . . — — . . (query)
ö — — — . (German ö or dipthong œ)
! — — . . — — (exclamation)
× . — . — . (end of message)
ü . . — — (German u or ue dipthong)
/ — . . — . (fractional bar)
“ ” . — . . — . (inverted commas)

The use of the American Morse Code on the circuits of this Company is prohibited, excepting where connection is made with a landline company.

Fig. 24-4 **Continental Morse Code** – A page out of a period Rules and Regulation book from the Marconi company.

installations for the quality of range attained by its use; the 'T' type was preferred for its greater adaptability in erection. The size of the aerial was limited by such considerations as the height of the ship's masts and the distance separating them. The type of aerial was chosen in accordance with its overall adaptability to the position of the operating cabin, ship's funnels, stays, etc.

On the great majority of the ships of the time, the entire distance between the masts could be utilized for the aerial because the natural wavelength of such an aerial was still less than that of the longer wave used at the time (600 meters). For the production of the short wave (300 meters), the aerials would almost invariably have their capacities decreased by means of a condenser in series which lessened the radiative power of the apparatus.

The natural wavelength of the aerial was between four and five times its length, so that in cases where the length of the aerial was considerably less than 200ft, the addition of a condenser in series for the short wave was unnecessary. In the case of *Olympic* and *Titanic*, the distance between the two masts was so great that if the aerial wires spanned the complete distance, a series condenser would be necessary. To compensate for this, the aerials were kept to a proper length, insulators added at their ends, and rope spans used at the after end of the array to make up the distance to the bridle that suspended the antenna array from the mainmast.

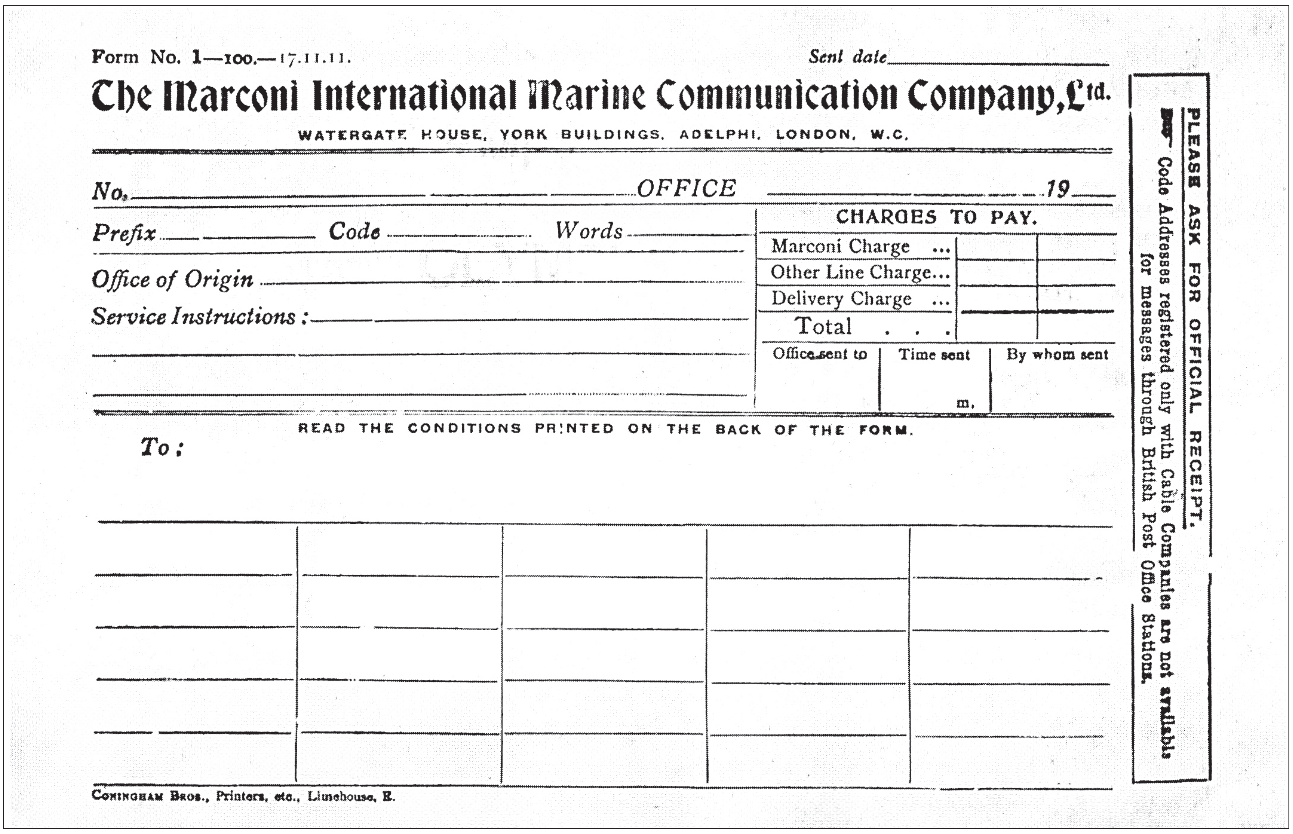
Aerial wires

Titanic's aerial wires consisted of four wires of $^{7}/_{19}$[6] silicon-bronze supported between two 20ft ash spreaders. Each of the four horizontal wires was the same length. The spreaders consisted of a pole, thicker in the center than at the ends, fitted at the corresponding spacing of the aerial wires with light malleable-iron double-lugged bands. A bridle of four 2½in-circumference ($^{13}/_{16}$in-diameter) steel wires attached to each spreader, with one wire attached to each of the bands, all four wires joining together into a single bight and thimble. The length of the individual bridle wires was such that the distance between the bight and the spreader was not more than 6ft or less than 3ft. The thimble on the forward bridle was secured directly to the foremast; the thimble on the after bridle was rigged to a galvanized steel wire rope which ran through an iron block on the mainmast and then down to the deck; by this arrangement the after end of the array could be lowered to the deck for periodic inspection and maintenance of the rope spans.

The wires of each twin 'T' aerial were spaced 6ft apart; the two twin sets were suspended parallel with each other 8ft apart. This gave the visual appearance of the two outside wires being spaced evenly apart with a wider space in the center.

The individual silicon-bronze wires were stranded and kept bare, as this gave the best performance and the least resistance. The wires of the aerial were carefully insulated where they entered the wireless cabin and at all points of support. With the 'T' form of aerials, it was necessary to use steadying guys running from the ends of each spreader to the deck, and as a consequence, insulators had to be inserted to isolate the silicon-bronze wires from the other components of the aerial array. At the forward end of the array, insulators were inserted between the aerial wires and the spreader; toward the other end, insulators separated the aerial wires from the rope spans leading to the after bridle. These insulators, termed 'strop insulators', were 3ft or longer in length, made of Palmer cord covered with rubber and vulcanized, with a thimble at either end.

Prior to fitting the aerials, it was necessary to determine the exact length of the wires. These figures could be taken from the builder's rigging plans or by



Form No. 1—100.—17.11.11.

Sent date

The Marconi International Marine Communication Company, Ltd.

WATERGATE HOUSE, YORK BUILDINGS, ADELPHI, LONDON, W.C.

No. ________ OFFICE ________ 19__

Prefix ______ *Code* ______ *Words* ______

Office of Origin ______

Service Instructions : ______

CHARGES TO PAY.

Marconi Charge ...

Other Line Charge...

Delivery Charge ...

Total . . .

Office sent to

Time sent

m.

By whom sent

READ THE CONDITIONS PRINTED ON THE BACK OF THE FORM.

To :

PLEASE ASK FOR OFFICIAL RECEIPT.

☞ Code Addresses registered only with Cable Companies are not available for messages through British Post Office Stations.

Coningham Bros., Printers, etc., Limehouse, E.

Fig. 24-5 **Blank Marconi Form** – A blank Marconi form of the same type used aboard *Titanic*. These would have been used by the Marconi operators to transcribe incoming messages for delivery to the recipient.

Fig. 24-6 **Editing the Newspaper** – An officer of a period liner edits the daily paper. *Titanic*'s was called *The Atlantic Daily Bulletin*. *(J. Kent Layton collection)*

actual measurement. The distance of the horizontal span was pre-calculated because it was intentionally shortened for short-wave transmissions, the remaining distance being made up by rope spans as previously noted. (On smaller vessels, the aerial wires were usually hung from mast to mast.) The center point of the four horizontal aerial wires was calculated, as well as the distance between the top of the wireless cabin and the center of the horizontal wires. Four lengths of wire were required equal to the distance from the forward end to the center point; four additional lengths were required equal to the distance from the after end to the center plus the distance from the center to the wireless cabin. For each section, the amount of catenary (sag) also had to be taken into account.

In making the measurement between the deckhouse and the aerial span, allowance was to be made for any extra length required for the staying-off of the aerial from parts of the rigging, etc. As the end of the wires had to be seized around 1½in heart thimbles in certain locations (such as the connection points of the spans, down-leads and lead-ins), an allowance of 6in had to be made for each thimble. Once the aerial had been rigged aloft, if all calculations had been properly carried out the four parts would be symmetrically disposed.

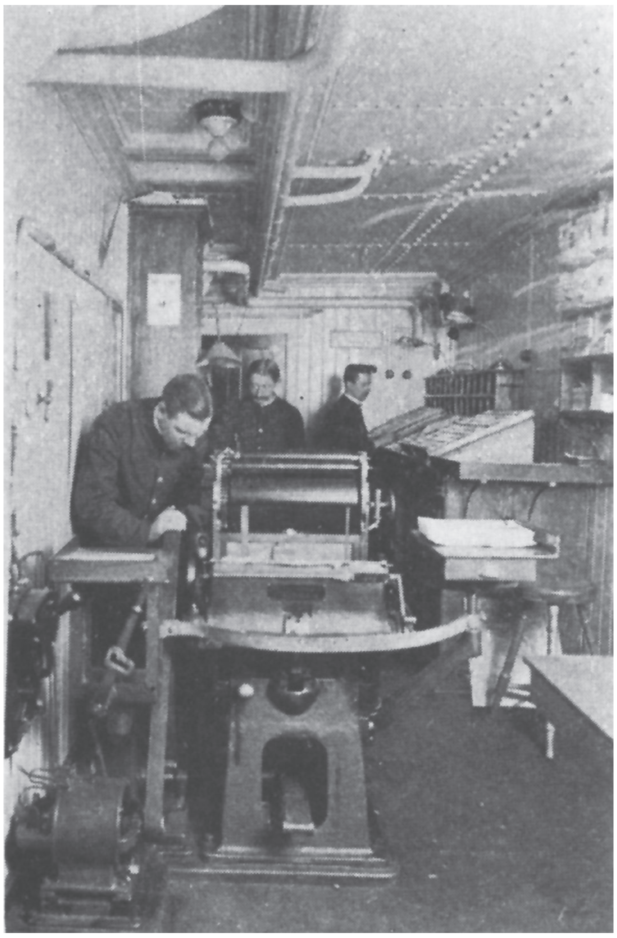


Fig. 24-7 **Printing the Newspaper** – A printing room onboard a liner of the day, with a printing press for creating, in addition to the daily paper, passenger lists, menus and notices. *(J. Kent Layton collection)*

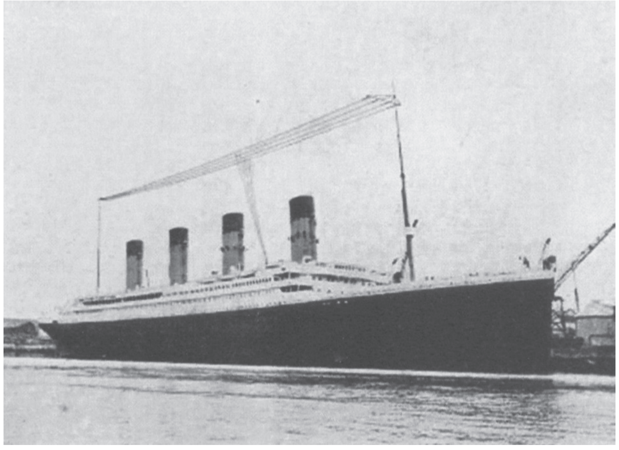


Fig. 24-8 **Twin T Aerials** – This image from an original Marconi publication purported to show *Titanic* with her 'twin T' aerials at Southampton. While this is indeed *Titanic* at Southampton, the aerials appear unnaturally bold in this photograph as they have been hand-drawn into the image for emphasis. This drawing is also inaccurate, as it shows the aerial wires with almost no catenary; here they appear as if they were taut and nearly straight.

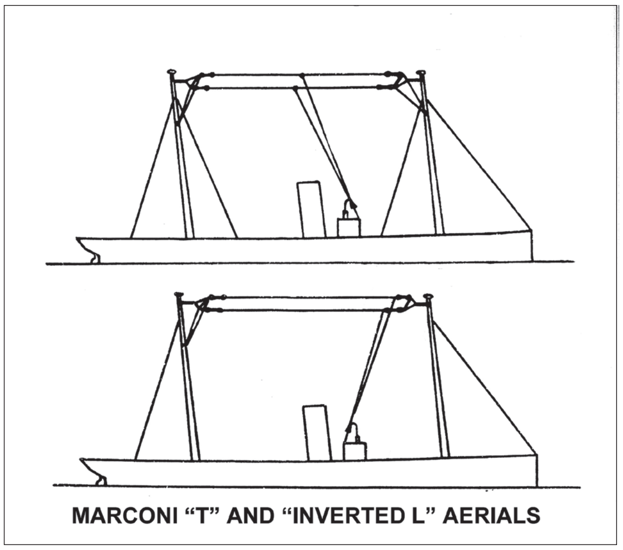


Fig. 24-9 **Comparison of 'L' and 'Twin T' Aerials** – A simplified illustration showing the two types of marine aerials commonly used at the time, the 'L' and the 'twin T,' and how they got their names.

Lead-in insulator

The lead-in insulator, known as the 'Bradfield', was a ½in steel rod which passed through a long ebonite tube of 1½in outside diameter. Each end of the rod was threaded, the lower end being fitted with a brass socket supplied with a wing nut and the upper end being supplied with a shackle head, a double brass lug and lock nuts. The insulator was led into the Marconi Silent Room through a stuffing box which consisted of a hollow casting through which the tube passed (the space between the inner face of the casing and the tube being occupied by seven asbestos packing rings) and an ebonite ring (fitted over the asbestos rings with pressure being brought to bear on it for the purpose of packing the asbestos tight by means of a flanged cap, which screwed on to the outside of the casting). The flanged cap had four notches cut round its periphery and a gland key was used to screw it home hard in order to fix the insulator in a rigid position through the roof of the cabin. The casting was firmly fixed by means of four coach screws (lag screws). The four aerial down-leads were reduced to two lead-in wires by joining the two wires in each pair of down-leads by thimbles to form a single wire. The two lead-in wires were given a turn or two around the shackle head after having been passed through the eye and were made fast in a double brass lug by means of two screws.

In ships where the Silent Room was located below the top deck, it was sometimes necessary to provide an 'aerial trunk' to carry the aerial through the intervening decks. This was not the case for *Titanic* as her Marconi

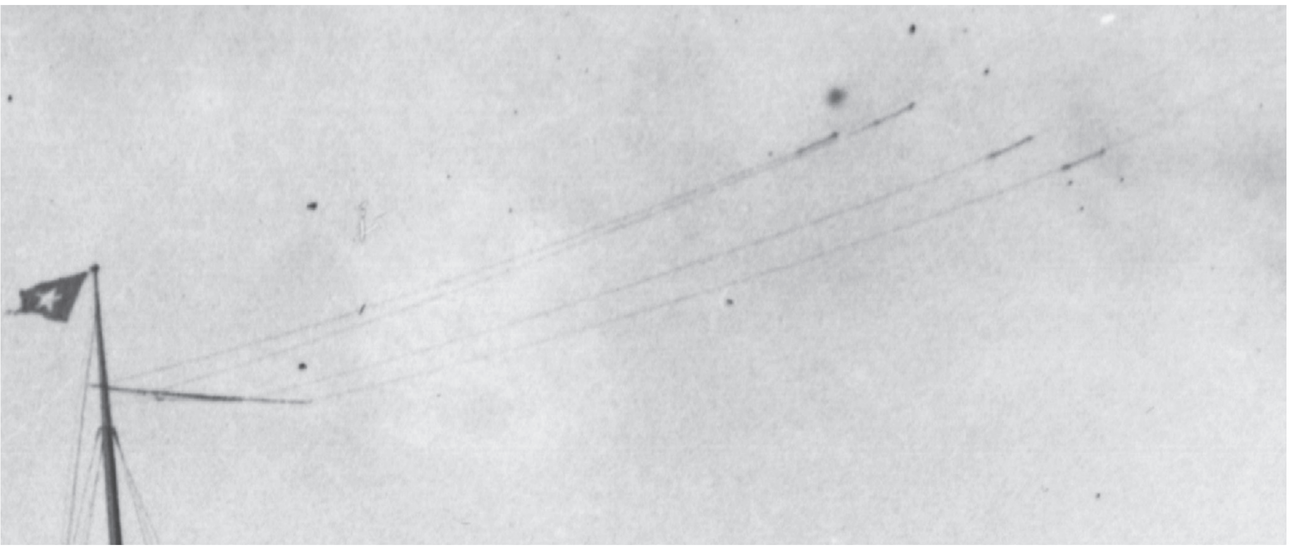


Fig. 24-10 **Rope Spans** – *Olympic*'s mainmast, showing the after aerial spreader and the rope spans between the aerial wires and the after bridle.

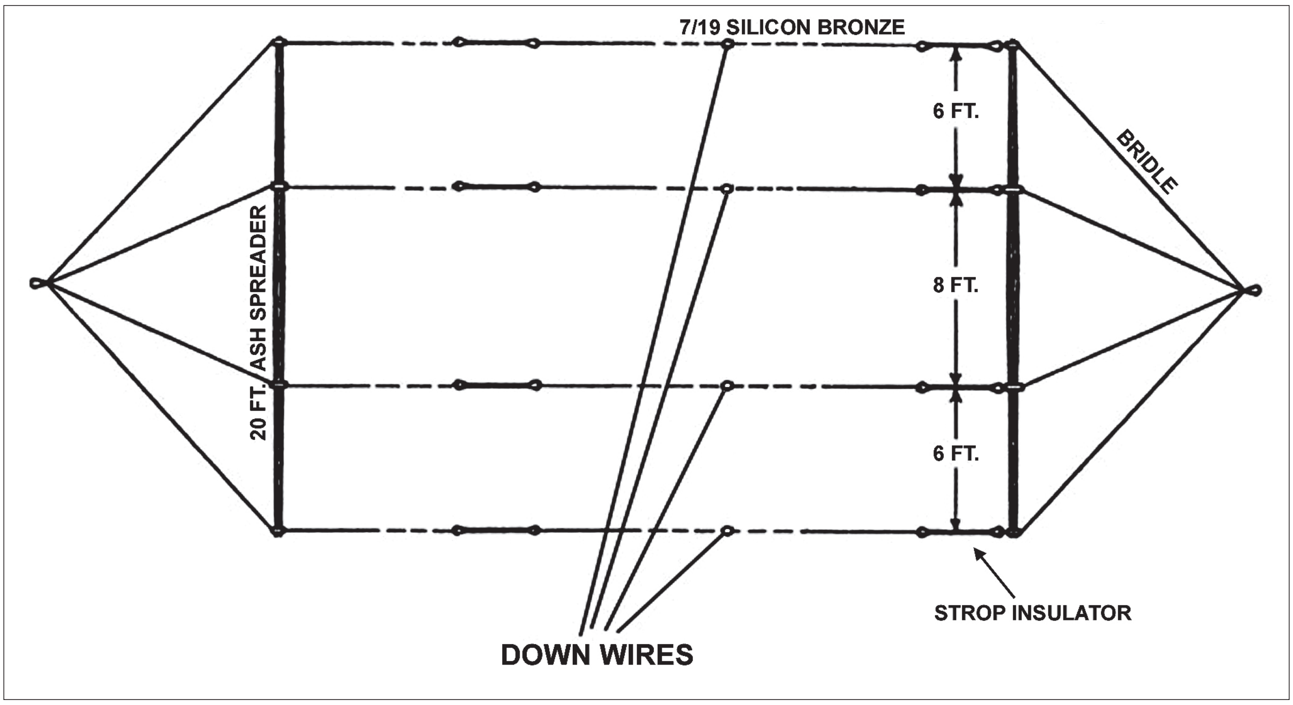


Fig. 24-11 **Wireless Aerial**.

Silent Room was directly beneath the steel-decked, wood-sheathed roof of the Officers' Quarters deckhouse. Instead, she was fitted with a square shaped 'aerial stack' or 'aerial mast', made of metal, about 6ft in height and approximately 10in x 10in in cross-section. This was necessary both to protect crewmen from electrical shock and to raise the Bradfield insulator above the height of an awning when it was fitted. The insulator was mounted at the top of the stack with a separate stuffing box mounted within the stack at deck level. The insulator was connected to the lower stuffing box via a steel rod through a threaded metal tube. A door was provided in the side of the stack in order that the insulators would be accessible for inspection.

The two down-lead wires were connected to the brass lug of the Bradfield insulator. The wires were kept slack, but in such a manner that there was no risk of them making contact with any part of the ship while swinging and such that no strain would be placed on the Bradfield insulator at any time. An ebonite strain insulator was attached to a guy connected to a suitable point on the down-leads; the lower end of the guy was made fast to a pad eye mounted on the deck over the Marconi Operating Room. A separate guy rope was

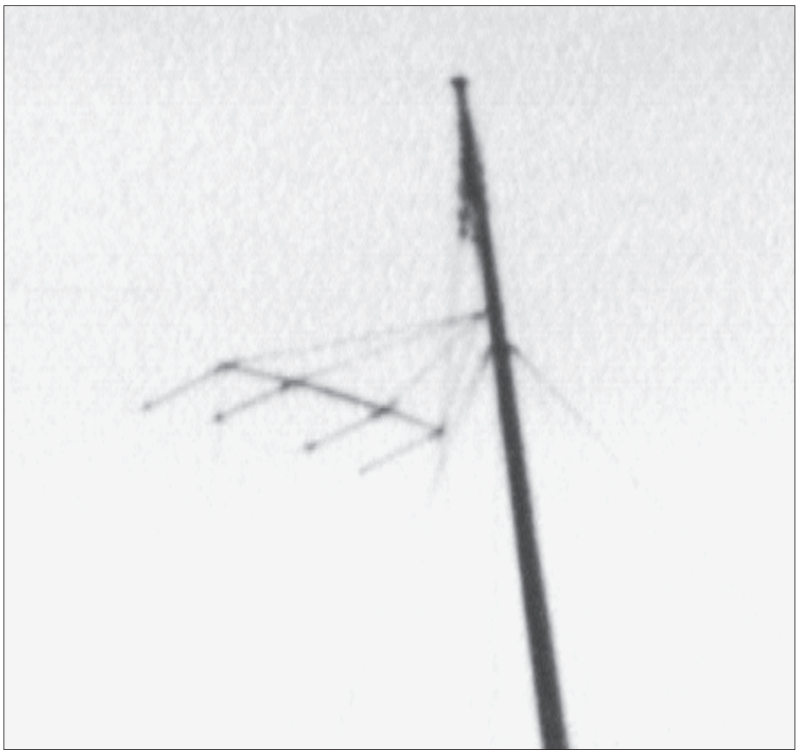
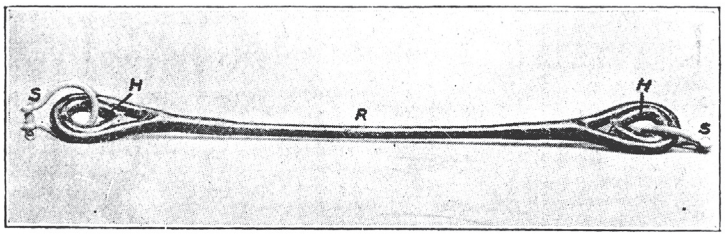


Fig. 24-12 **Aerial Spreader on *Titanic*** – *Titanic*'s forward aerial spreader.



Strop Insulator.

R, Insulator Proper.—S, Galvanised Iron Shackle.—H, Heart Thimble.

Fig. 24-13 **Strop Insulator**.

utilized to keep the strain off the lead-in wires when the ship was rolling. It was made fast in a position that pulled the down-lead wires forward and to compensate for excessive swinging.

The Wireless Installation and Components

The following information is a general breakdown of *Titanic*'s wireless installation and its components. It was gathered from many sources, but none was more valuable than the first edition of the *Handbook of Technical Instruction for Wireless Telegraphists* written by J.C. Hawkhead and published by the Marconi Press Agency in 1913. This book, along with its subsequent editions, details almost in its entirety the 5kW wireless set that was used aboard *Titanic*. It is from this source that much of the following information has been presented.

[Note: the remaining material in this chapter is presented for those readers who may be interested in the technical workings of Titanic*'s Marconi installation. As this necessarily involves material of a highly technical nature, a working knowledge of radio theory and/or electronics will be required.]*

To understand the circuits utilized in shipboard wireless telegraphy, a simple explanation of the functioning of this apparatus follows. Direct current at 100 volts entered the motor armature through the starting box and set it into rotation. The alternator, which was direct coupled to the motor, in turn generated alternating current varying from 100 to 300 volts.

When the telegraph key was closed, current flowed from the generator armature through the primary winding of the transformer setting up a magnetic field, inducing a current of 10,000 to 20,000 volts in the secondary winding.

The voltage and the frequency of the alternating current could be adjusted by the generator field rheostat and the

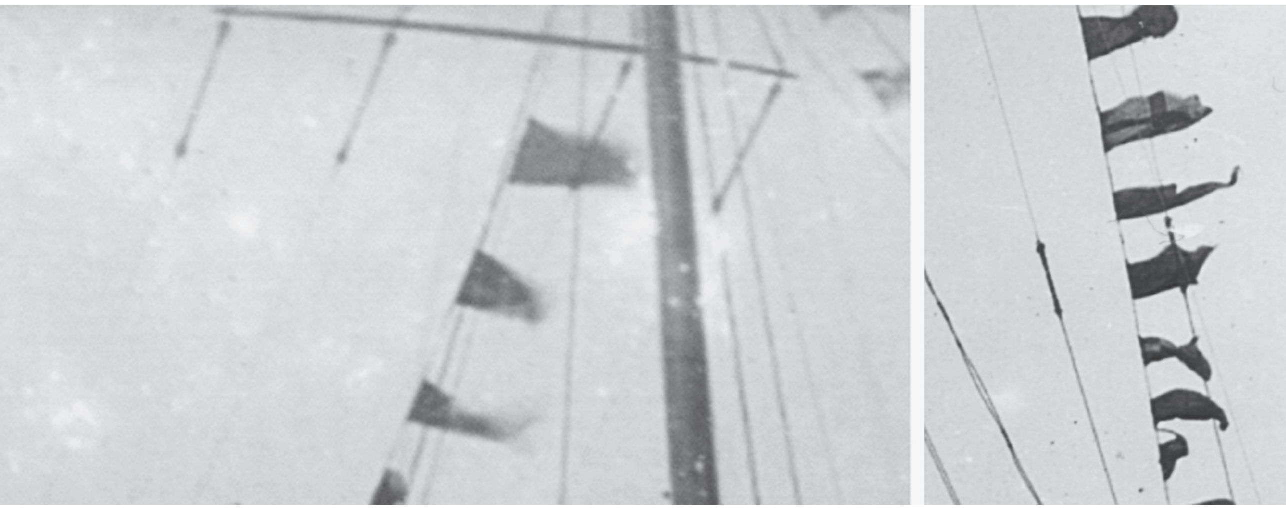


Fig. 24-14 **Spreader and Strop Insulator** – At left, the forward aerial spreader on *Olympic* in 1911. At right, a strop insulator between one of the rope spans and its aerial wire. *(Both images authors' collection)*

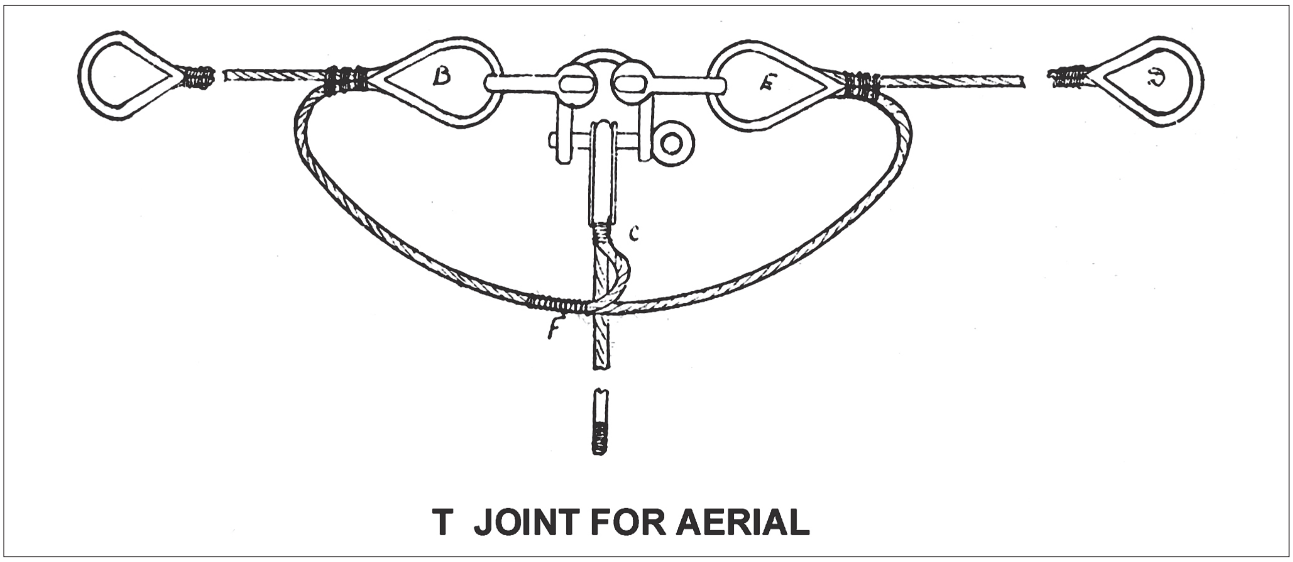


Fig. 24-15 **T-Joint for Aerial –** This example shows how and where the thimbles should have been fitted in the case of the Twin-T aerial. One end of the longer pieces were taken around a 1½in heart thimble and seized with No.20 soft copper wire, the seizing being afterwards soldered as shown at *A*. At the point *B*, about 4in from the point corresponding to the center of the aerial span, another heart thimble was seized, and a third one being fixed at point *C*. A similar thimble was seized at one end of one of the shorter lengths *D*, and another one about 4in from the other end, *E*. The remaining end, *F*, of the shorter length was seized and soldered to the longer length at *F*. The three thimbles, *B*, *C* and *E*, were connected together by means of three galvanized iron shackles.

motor field rheostat. For example, if resistance was added at the motor field rheostat, the motor would increase its speed and, accordingly, the frequency of the generator would be increased. This would also tend to increase the voltage of the generator. If resistance were added to the generator field rheostat, the voltage of the generator armature would be reduced; conversely, if the resistance of the rheostat was decreased, the voltage of the generator would increase.

The terminals of the secondary winding of the high-voltage transformer were connected to terminals of a battery of condensers where the energy was stored up temporarily in the form of electrostatic lines of force. When the limit of charge for each alternation of charging current had been reached, the condenser would discharge across the spark gap through the primary winding of the oscillation transformer, the discharge consisting of a number of radio-frequent oscillations. The frequency of the oscillations would decrease if inductance was added at the primary winding or increase if the inductance was reduced. An increase or decrease of the capacity of the condenser affected the frequency in the same manner; e.g., a reduction of capacity would increase the frequency of the oscillations while an increase of capacity would reduce the frequency of the oscillations.

The oscillations flowing in the closed circuit when the manipulation key was depressed were transferred

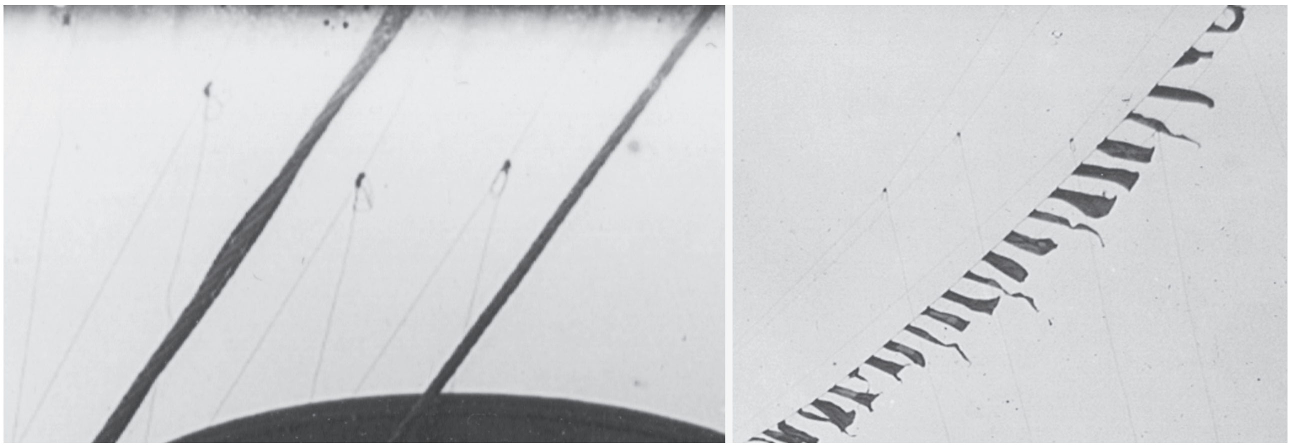
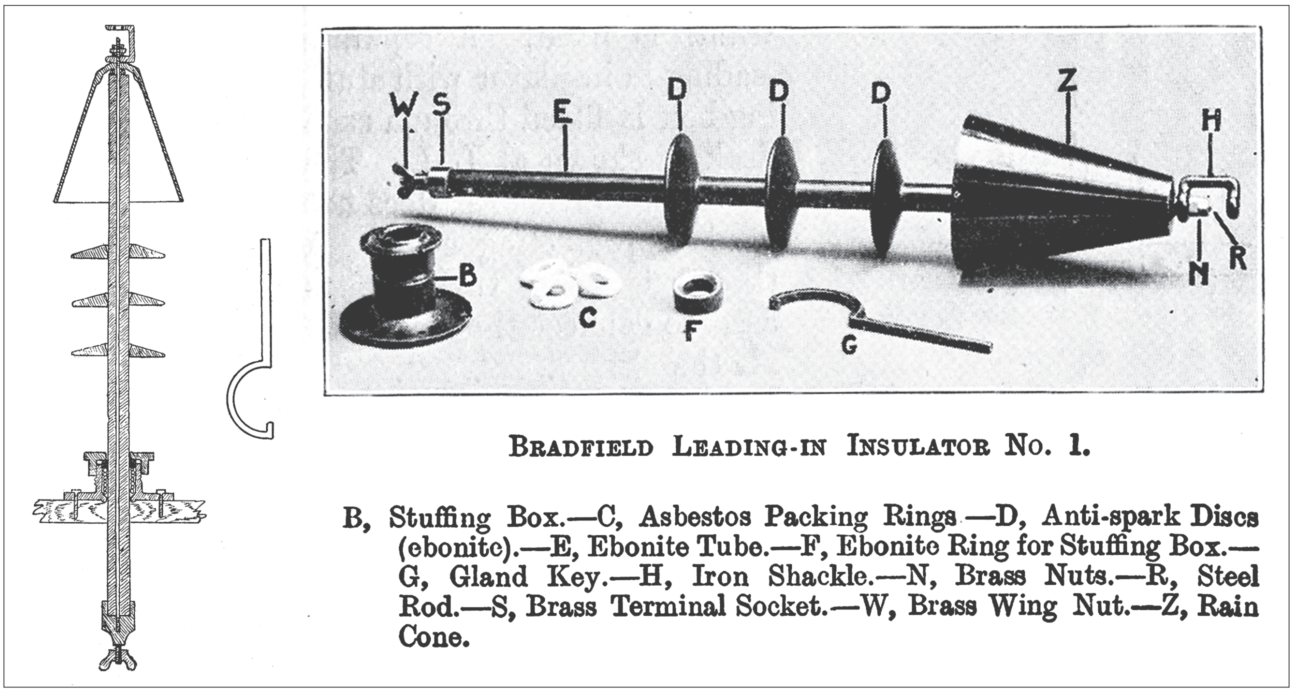


Fig. 24-16 **T-Joints aboard *Olympic*** – T-joints as seen on *Olympic*'s aerial spans.



BRADFIELD LEADING-IN INSULATOR NO. 1.

B, Stuffing Box.—C, Asbestos Packing Rings.—D, Anti-spark Discs (ebonite).—E, Ebonite Tube.—F, Ebonite Ring for Stuffing Box.—G, Gland Key.—H, Iron Shackle.—N, Brass Nuts.—R, Steel Rod.—S, Brass Terminal Socket.—W, Brass Wing Nut.—Z, Rain Cone.

Fig. 24-17 **Bradfield Insulator** – The Bradfield Insulator. The anti-spark disks labeled here as 'D' were not on the version installed on *Titanic* and *Olympic*.

to the aerial circuit through the oscillation transformer. This energy was used to recharge the condensers, while a portion of the remaining energy was radiated from the antenna in the form of electromagnetic waves.

If a receiving aerial was erected at a distant station and its natural time period of oscillation adjusted to the frequency of the oscillations flowing in the transmitting aerial, the fluxes of the advancing wave would induce currents in the receiving aerial, having substantially the frequency of the oscillations in the transmitting aerial. The apparatus within the station could then convert these currents into an audible signal which would be heard in the receiving telephone.[7]

The rotary spark

To increase the range over which transmission was possible, it was not only necessary to provide a powerful dynamo for furnishing the necessary energy, but also to devise some form of spark gap which would generate the necessary electrical oscillations with as little loss of energy as possible. To address the problem, Guglielmo Marconi designed a high-speed rotating disc discharger; a description of the device was given by the inventor in a lecture before the Royal Institution in March of 1908.

Marconi created the 'rotary spark', which was first installed in his Clifden land station on the west coast of Ireland in 1908. The basic make-up of the device consisted of an insulated metal disc that was rotated by means of a high-speed motor. Two discs known as 'polar discs' were

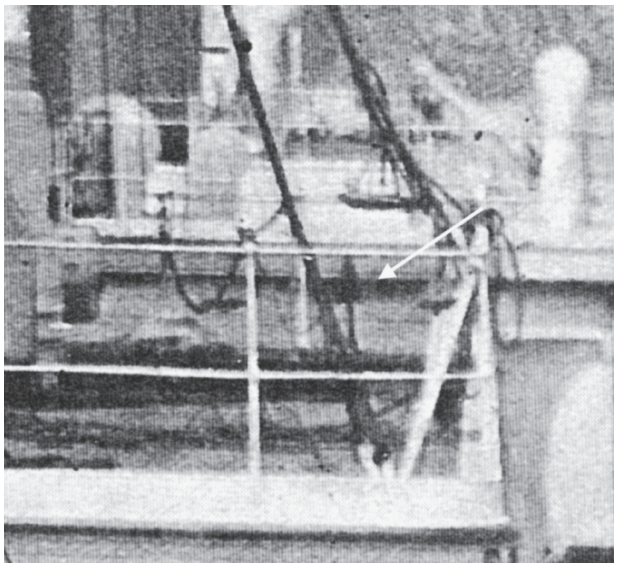


Fig. 24-18 **Bradfield Insulator on *Olympic*** – The Bradfield insulator on *Olympic* is indicated here with an arrow. *(Daniel Klistorner collection)*

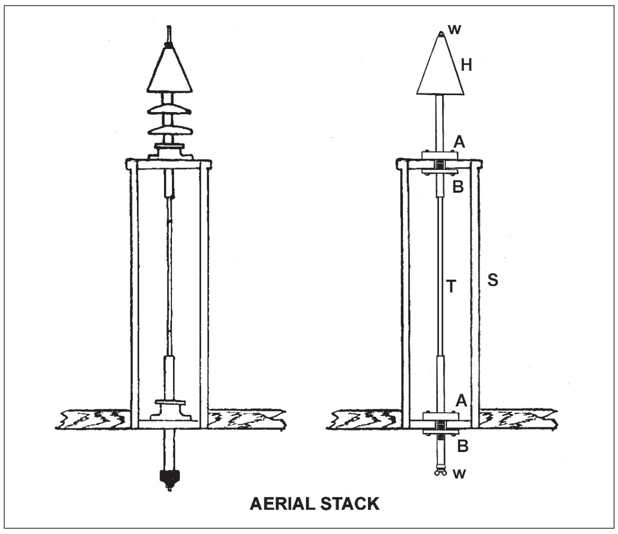


Fig. 24-19 **Aerial Stack** – The 'aerial stack' as opposed to an 'aerial trunk.' A 'trunk' passes through one or more interior levels, whereas a 'stack' stands above the surrounding structure such as what was fitted to *Titanic*. This raised fitting has also been termed an 'aerial mast.' Aboard some ships the Marconi Operating Room was below the top deck necessitating a trunk to provide a protective enclosed passage through which the aerial conductor could be led to an open deck above. On *Titanic*, the Operating Room was within the Officers' Quarters Deckhouse. Pictured here are two variations of the elevated Bradfield Insulator on a stack. At left is an older version with stuffing gland and two spark disks as seen in the detailed illustration of the Bradfield insulator. At right is an alternate version found in an American Marconi reference book. The 5kW disc discharger on *Olympic* and *Titanic* were new variations over the 5kW spark gap discharger that was supposedly intended to be originally fitted on *Olympic* in 1911. Evidence suggests that somewhere in the process, the Marconi company upgraded *Olympic*'s installation from the earlier 1½kW set to the significantly more powerful 5kW disc discharger very early in her career. In all likelihood, the aerial lead-in was upgraded at the same time to deal with the increase in power. Photographs show the Bradfield insulator design employed aboard *Titanic* did not have the two spark discs.

The stack *S* was of square section and, per Marconi design requirements, was not to be less then 10in across. (The profile of the aerial stack shown on the H&W Rigging Plan suggests a dimension of approximately 18in.) *T* was a long, hard rubber tube about 2in in diameter with a brass rod extending through it which terminated at each end in a wire connecting lug *W*. The tube was threaded at the center to take two wooden blocks, *A* and *B*. After the blocks were drawn up tightly, the bolts were inserted. To ensure a watertight joint, a piece of canvas strip was laid underneath the blocks and thoroughly covered with white lead. A metal hood, *H*, fastened to the exposed end of the tube protecting it from dampness. Doors were let in the side of the stack to allow inspection of the interior. It was necessary to use a stack in order to raise the Bradfield insulator above the level of an awning that could have been fitted over the Officers' Quarters Deckhouse on *Titanic*.

placed perpendicular to the main disc, so that the edges of all three discs were close together, the main disc being situated centrally. The two polar discs were caused to rotate and were connected by means of bushes through inductance coils to the terminals of two condensers joined in series. To these terminals were brought the leads of a high-tension continuous current dynamo, which furnished the power for the system. A second oscillatory circuit was provided from the middle of the condenser system through a condenser and inductance coil to the central rotating disc. A discharge from one of the polar discs to the main center disc charged and set up oscillations, causing a further discharge between the center disc and the other polar disk. This completed a cycle that went on indefinitely, and powerful oscillations were developed in the oscillatory circuit. By means of this apparatus it was possible to obtain oscillations of a frequency as high as 200,000 per second. Marconi further improved on the rotary spark gap by making it synchronous, which caused it to produce a musical note while in operation. The harmonious rotary spark gap was more effective than the older induction coil spark transmitter. An improved version of the Clifden 'singing' rotary spark would be installed on *Titanic*.[8]

5 kW Transmitting Apparatus

The direct-current circuit

The first circuit to be considered in *Titanic*'s wireless installation is the direct-current circuit. This circuit contained four pieces of apparatus – the main switch, the starter, the field regulator and the alternator. The 5kW set was supplied with a motor-generator set which was simply a motor and alternator coupled together on a common cast iron base. The motor drove the alternator,

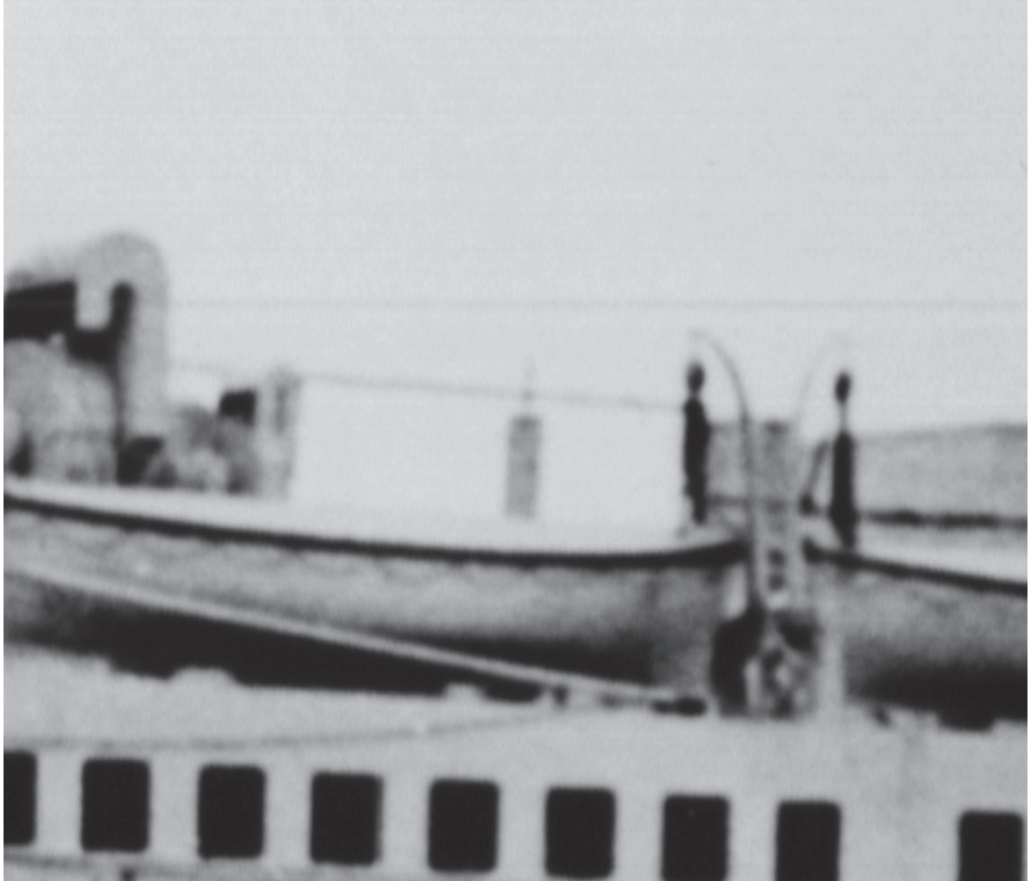


Fig. 24-20 **Aerial Stack on *Titanic*** – In the center, just above the lifeboat, is the aerial stack as seen on the *Titanic*.

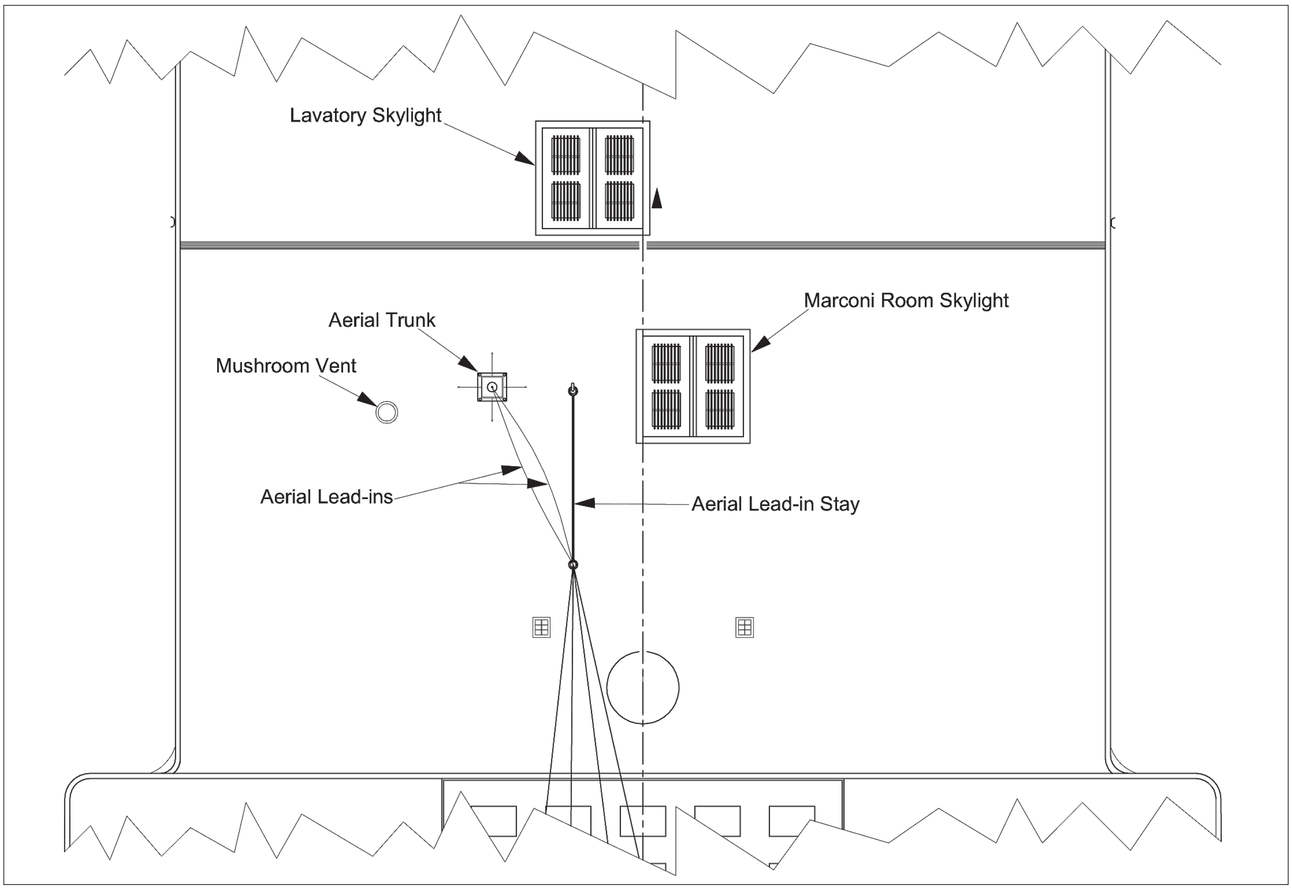

Lavatory Skylight
Marconi Room Skylight
Aerial Trunk
Mushroom Vent
Aerial Lead-ins
Aerial Lead-in Stay

Fig. 24-21 **Roof over Marconi Rooms** – The roof of the Officer's Deckhouse over the Marconi rooms. Illustrated in this plan view are the many fittings associated with the aerial array and general ventilation layout. *(Illustration Bob Read)*

thereby converting the 100 volts direct current (DC) from the ship's mains into 300 volts alternating current (AC) at 60 cycles per second.

Main switch

The ship's power supply was led to the wireless compartment and fixed to a main switch incorporated in a DC marine switchboard which consisted of a voltmeter, ammeter, 100 ampere cartridge fuses and a pilot lamp. This switch was used to isolate the whole wireless installation from the ship's mains. The switch was of the double-poled,

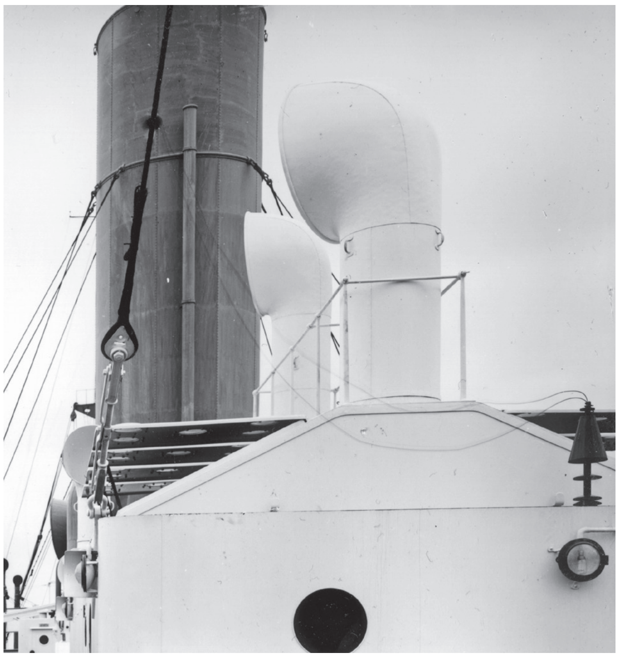


Fig. 24-22 **Insulator aboard *Deseado*** – The Marconi aerial connections and Bradfield Insulator of the Harland & Wolff-built ship *Deseado* of the Royal Mail Steam Packet Line, captured in this June 1912 photograph. *(H&W/Authors' collection)*

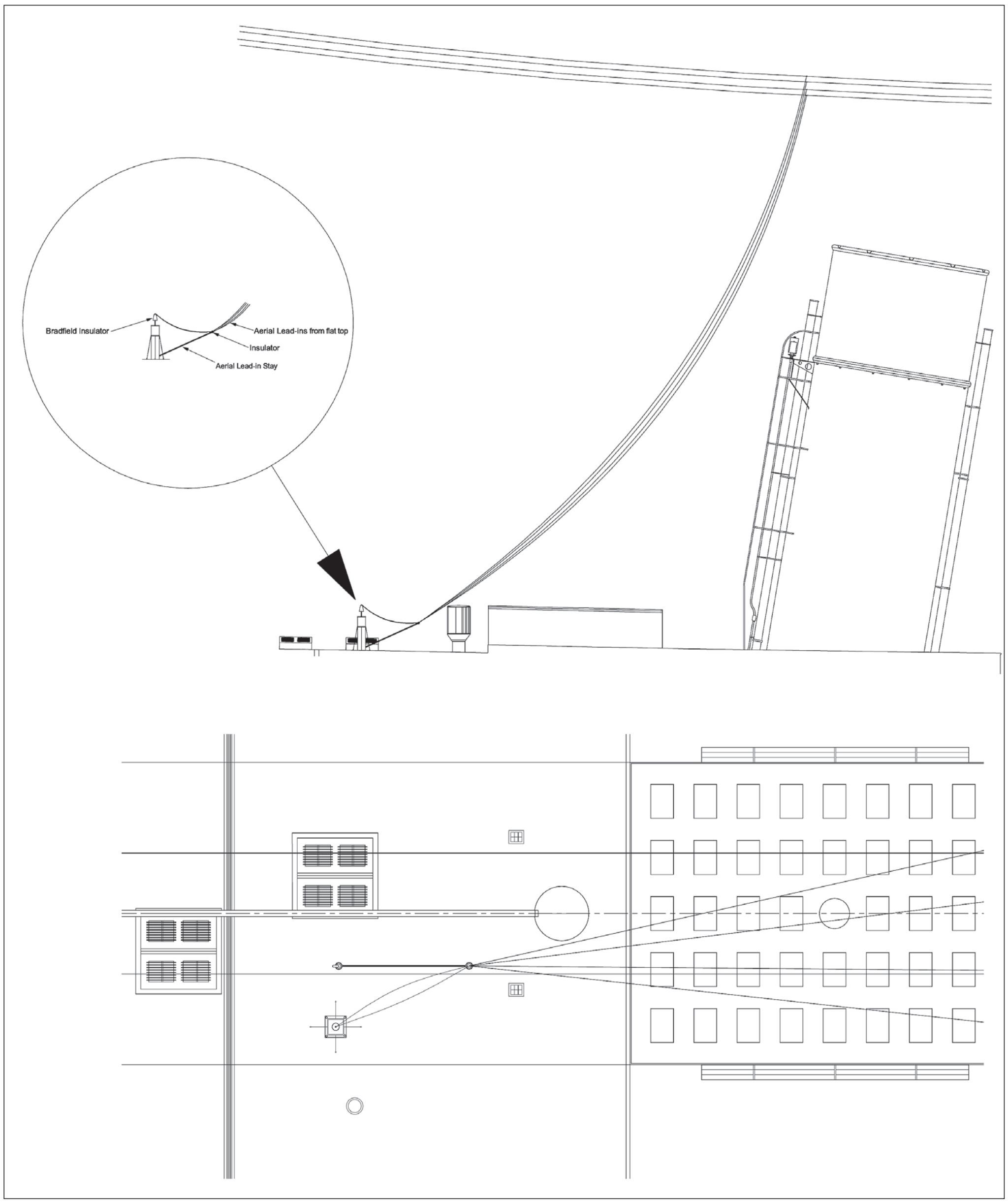


Fig. 24-23 **Aerial Down-Lead** – This illustration shows the configuration and location of the aerial down-leads, aerial stack and lead in stay on the roof of the Officers' Quarters deckhouse. *(Illustration by Bob Read)*

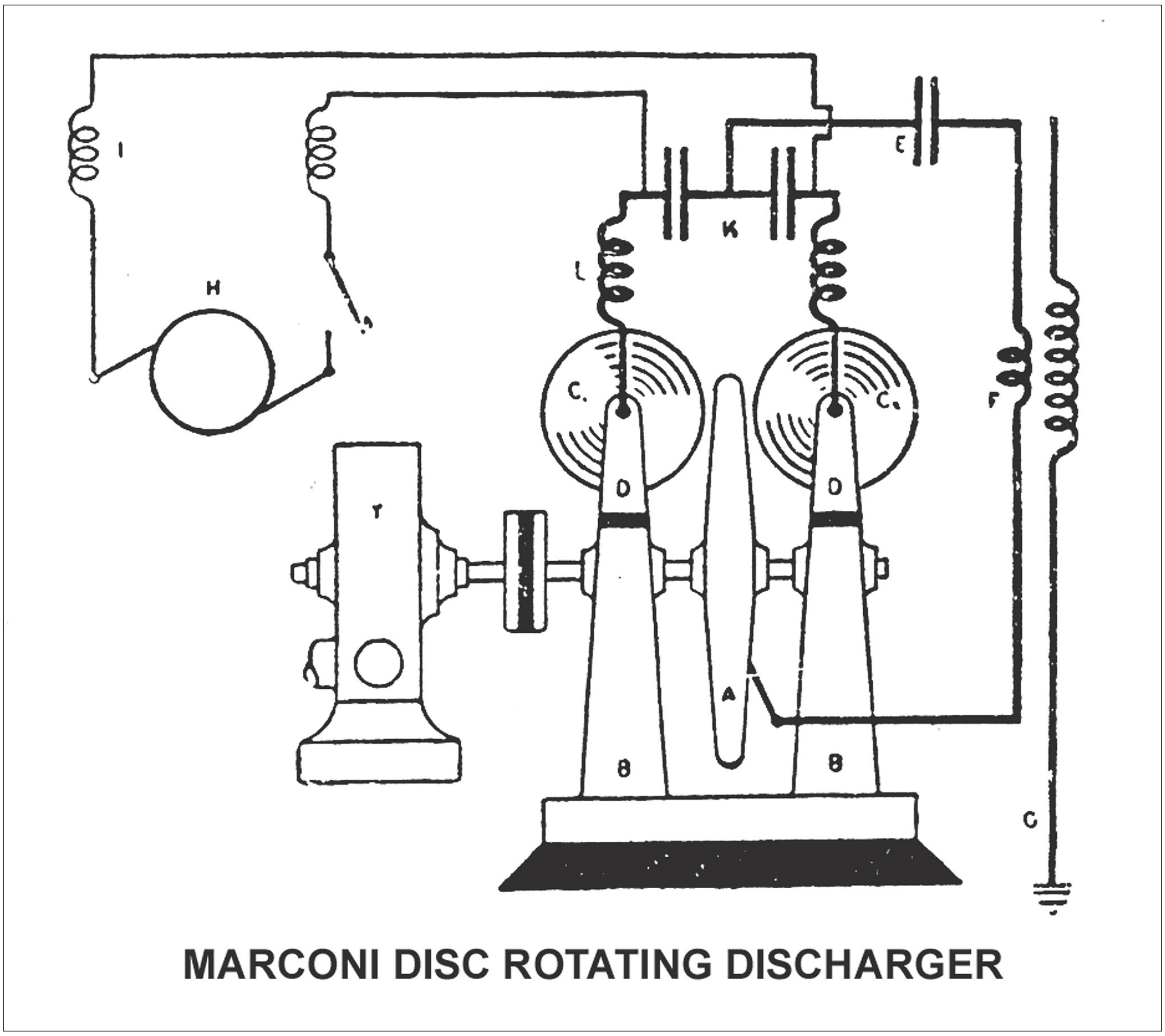


Fig. 24-24 **Disc Rotating Discharger** – An insulated metal disc *A* was rotated by means of the high speed motor shown on the left of the Figure. Two discs *C1* and *C2*, known as polar discs, were placed so that the edges of all three discs (*A*, *C1* and *C2*) were closer together. The two polar discs were caused to rotate, and were connected by means of bushes through inductance coils *L* to the terminals of two condensers *K* joined in series. To these terminals also were brought the leads of a high-tension, continuous-current dynamo, which furnished the power for the system. A second oscillating circuit was provided for the middle of the condenser system *K* through a condenser *E* and inductance coil *F* to the oscillating disc *A*. The discharge from *C2* to *A* charged *E* and set up oscillations, causing a further discharge between *A* and *C1*, the charge on the later being opposite to that on *C2*. This completed a cycle which went on indefinitely, and powerful oscillations were developed in the oscillatory circuit *EF*.

knife contact type. By dividing the switch arm into two parts and connecting the two parts by means of a spring, a means of breaking the circuit was quickly obtained.

Starter

The starter was designed to impress a small voltage upon the armature of the motor and, by gradually cutting out resistance in series, to increase the voltage to its maximum by suitable steps. If the motor was started too quickly or too slowly, damage could result to the armature. It was much the same in appearance and design as the earlier 1½kW device, only with an additional electro-magnet mounted to its slate face. This was an overload release of such design that when the current exceeded a certain amount, an armature would be attracted upwards where it made contact with a stop, thus short-circuiting the 'no-volt' release and allowing the starting handle to fly back to the 'off' position. The design of this armature was such that it afforded a means of setting the overload release to any value between certain limits. The lower end of the armature was supported on a slotted brass strip which had its lower end bent at right angles. The position of this strip, which was marked with a scale of amperes, was adjusted with respect to the coil by means of a screw, so that any current exceeding the amperes shown on the scale was capable of causing the armature to be attracted.

Motor field regulator

The field regulator was somewhat similar in appearance to the starter. It consisted of a series of resistance coils connected to a set of brass studs fixed on the face of a slate slab. The first and last studs were respectively marked 'in' and 'out'. Two terminals were supplied at the base of the slate face, the left-handed terminal being connected internally to the pivoted end of the regulating handle and the right-handed terminal being connected internally to the last stud marked 'out'. The left-hand terminal was also connected to the 'in' end of the resistance to prevent the circuit being broken as the result of a bad contact made by the regulating handle. The handle was of much lighter nature than that of the starter; the brush contact had only to carry small field currents as it was to be capable of being left permanently on any stud, the handle (unlike the starter) was not fitted with a spring return. Variation of the motor field regulator could alter the speed and increase the alternating voltage.

Alternator field regulator

The generating part of the machine was slightly different than the type of dynamos seen on earlier Marconi sets in that the part which revolved was the 'field' and the stationary coils disposed round the inside of the framework were the ones in which the alternating current was 'induced'. Because of its design, the alternating current was not taken from slip rings on the generator shaft, but from two fixed cables which were led out from the stationary windings.

The strength of the induced alternating current depended on the intensity of the revolving field and means were supplied for varying this intensity. The revolving field coils were connected through a pair of slip rings mounted on the generator shaft and through a variable regulating resistance to the direct-current supply from the ship's mains. The regulating resistance was very similar to the field regulator of the motor in appearance and its use was to adjust the cycles of the rotary spark.

Machine protecting shunts

Two guard lamps were used across the field and armature of the motor, as was the case in the 1½kW set. In the case of the generating part of the motor-generator, protection was afforded by means of two graphite sticks which were mounted on a baseboard carrying a spring clipping device. A graphite stick was connected in shunt across the armature leads and another one across the field leads as a discharge circuit to protect the respective windings from the effects of any oscillatory surges, which could be induced from the high frequency circuits during wireless transmission. These protective shunts were usually mounted on the bulkhead within close proximity of the motor and generator.

Low Frequency Primary Circuit

Alternating-current switchboard

From the motor-generator, the alternating current was taken to a switchboard. This piece of apparatus consisted of a slate panel mounted on a cast-iron frame right next to the direct-current switchboard. Being very close in appearance to its direct-current counterpart, it was fitted with an ammeter with short-circuiting plug, a voltmeter with key, a double-pole knife switch, fuse ways and a pilot lamp. The pilot lamp was to glow when the machine was running and was to be immediately replaced when burnt out. The ammeter was to be kept short-circuited when not in use. The feeding mains were brought from the generator to the lower extremities of the knife blade switch. The ends of the double-pole knife switch were also permanently connected to the pilot lamp, so that

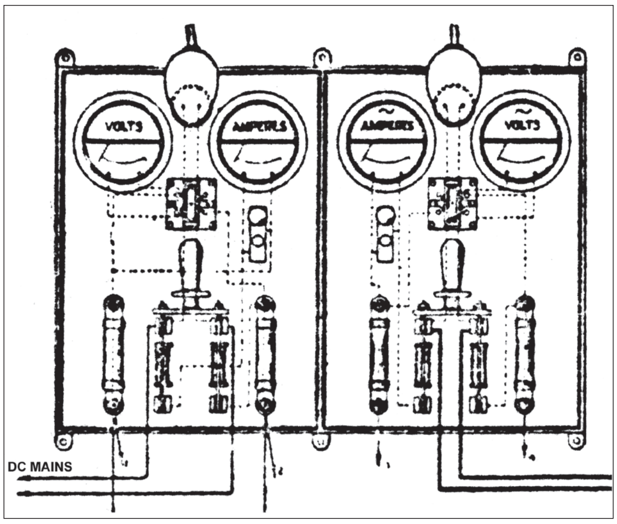


Fig. 24-25 **Main Switches** – The DC main switch, at left, and the AC main switch, at right, both of the Iolanda design. These were usually seen next to each other as in this example.

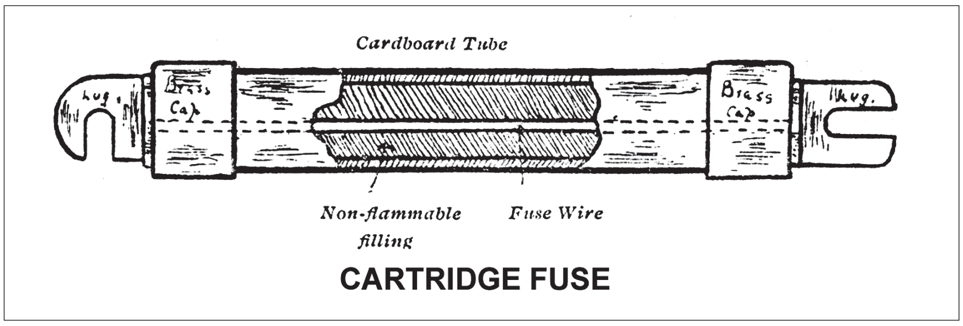


Fig. 24-26 **Cartridge Fuse**.

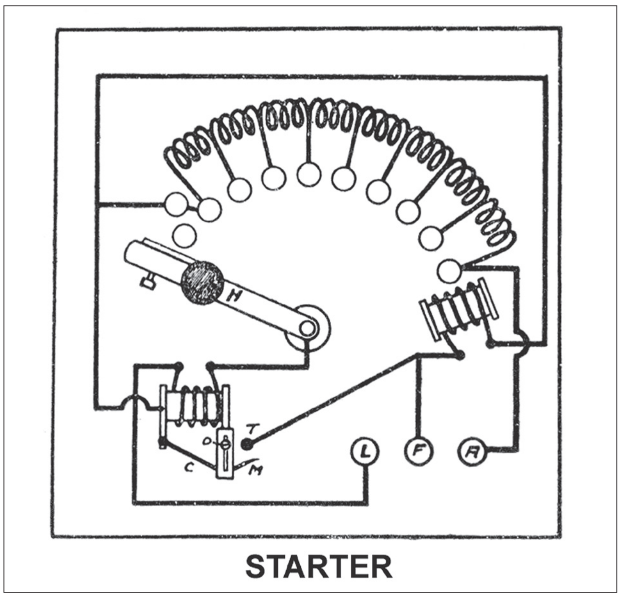


Fig. 24-27a **Starter Schematic** – *C* – Armature, *T* – Stop; *H* – Starter Handle; *M* – Lower end of armature supported on a slotted brass trip with lower end bent at right angles; *D* – adjustment.

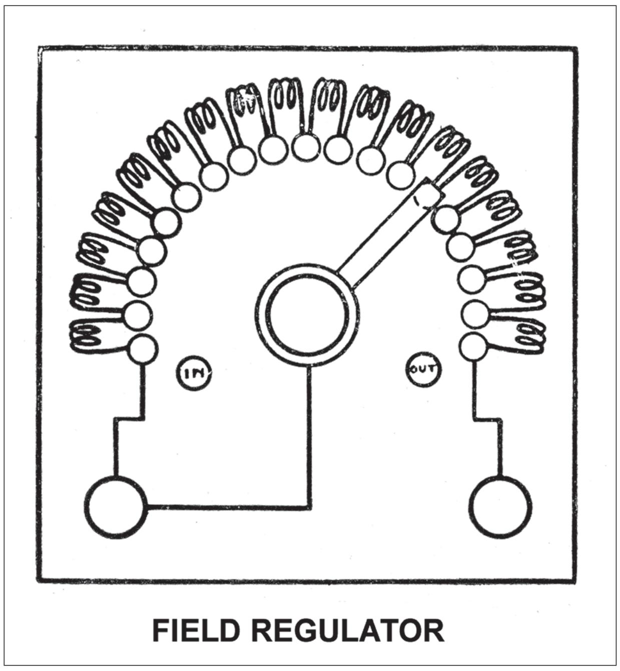


Fig. 24-27b **Field Regulator Schematic**.

when the alternator was supplying alternating current to the switchboard, the lamp would glow whether the switch was closed or open.

The low-frequency iron-core inductance

This device was fitted in the transformer primary circuit. It consisted of a winding on an open iron core, having a number of tapping connections brought to the brass contact studs of a regulator. The coil was enclosed in a ventilated teak box mounted on porcelain feet. It had a maximum value of 0 to 19 henry depending on the electrical constants of the rest of the circuit, and was adjustable in multiple steps.

Manipulating key

The main manipulating key was not the same in appearance as the commonly compared Morse key used on land. The manipulating keys for both the main and emergency Marconi sets of *Olympic* and *Titanic* had an added safety side lever to break the circuit if necessary; this lever was located to the left side of the wooden block. The main manipulating key was located in the center of the instrument. It consisted of platinum contact pieces of a rather large cross-section, an ebonite knob fitted to a brass bar forming the key. The play of the key could be regulated by means of an adjustable backstop and the tension on the key by means of a spring. The manipulating key was wired to the double magnetic relay key to provide low voltage to the instrument, thus protecting the operator from electrical shock.

Double magnetic relay key

The electromagnetic force of an alternating current continuously changes in direction and magnitude. If the circuit was broken at the manipulating key at a moment when this value was at a maximum, a spark was formed at the contacts which, in addition to burning away the expensive platinum, made the contacts dirty and prevented rapid working. In order to obviate these two evils a double magnetic key was introduced.

As was already stated, the primary alternating current was delivered from the motor-generator at anything between 100 and 300 volts and a shock from such a source would be quite unpleasant. By using a double magnetic relay key, it was possible to work the manipulation key on a low voltage. A direct current of low voltage, or of the same voltage as supplied by the motor, was passed through the latter and through one pair of coils in the former, thus actuating an armature that closed the alternating-current low-frequency primary circuit. Because a second path had been provided for the current, eliminating excessive spark, the operator was allowed to work without distraction.

Transformer

The closed iron-core type of the transformer was fitted wherever a disc discharger formed a part of the transmitter. It consisted of a continuous primary winding and a secondary divided into two parts. It was contained in an oil-tight galvanized tank filled with high-flash insulating oil. The two ends of the primary were brought through heavy ebonite bushes to one side of the container, the four ends of the divided secondary being similarly brought to the opposite side. The secondary terminals were fitted with two brass straps by means of which the two parts might readily be connected either in series or parallel. The transformer was capable of delivering 5 kilovolt-amps at either 10,000 or 20,000 volts when supplied with alternating current at 300 volts. Such an output was capable of supplying sufficient charging energy to the condenser arrangement for wavelengths

HIGH-TENSION CIRCUIT

The next circuit to be addressed was called the high-tension or high-voltage circuit, the main parts of which were the transformer secondary windings, two air-core choke coils and the main condenser. The transformer has already been addressed previously.

The air-core choke coils

The function of the choke coils was to prevent the high frequency condenser discharge current from surging back into the low frequency circuit, without interfering in any way with the low frequency condenser charging current. Each coil was wound with enamel-insulated wire in a single layer on an insulated former contained in a teak box. The value of the frequency in the case of the alternating current was so low that the current had no difficulty in passing through them. As oscillating currents in which the frequency had an exceedingly high value were circulating and, as the main condenser was common to the two circuits, these chokes prevented the oscillating currents from passing back to the transformer windings because the value of the impedance for the extremely large value of frequency was too great to permit such a flow of current.

The choke coils, because they conveyed the charging current, were often connected to the oscillatory circuit at the condenser. This was the best position to make them resonate should the wave in the condenser circuit approach that of their period, which was to be avoided. They were always designed to have a much greater period than the maximum of the condenser circuit, but it was an added safeguard to connect them at the discharger instead of the condenser as resonance effected in them was then minimized.

THE CLOSED OSCILLATORY CIRCUIT

Main condenser

This piece of apparatus was used to store up the energy for the production of the oscillating currents in a closed oscillatory circuit. The complete condenser bank could be varied over a wider range of capacity than was possible in Marconi's smaller-power sets. It consisted of four units which were mounted on two teak stands having porcelain feet. A wooden framework was erected round the bank in such a manner that a controlling device could be placed immediately above the condensers, by means of which different parallel, series, or series-parallel arrangements of the separate units could be easily affected. Each bank was contained in a separate galvanized iron tank filled with high-flash insulating oil. Each unit was made up of thirty-six glass plates, interleaved with seventeen zinc sheets with two glass plates between each pair of zincs; the condenser consequently became known as a 'full plate' condenser.

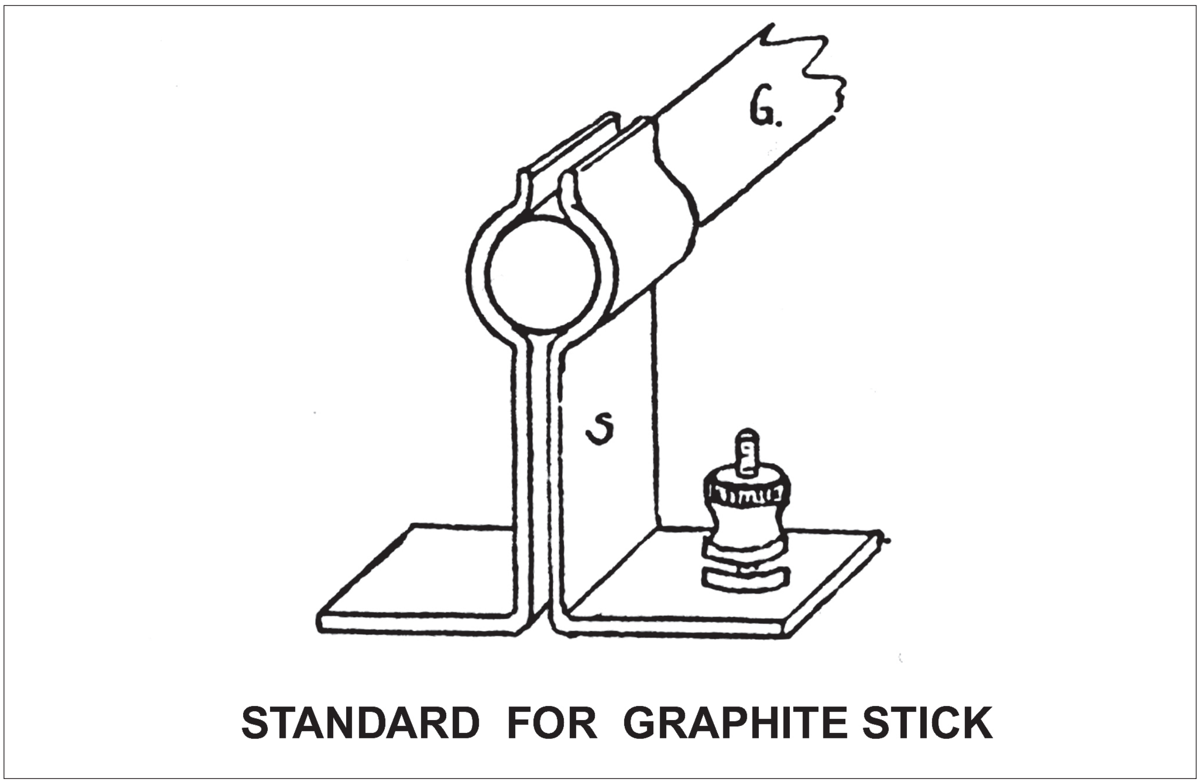


Fig. 24-28 **Graphite Protective Shunt** – Graphite stick *G* clipped between the bent upper ends of the brass springs, *S*.

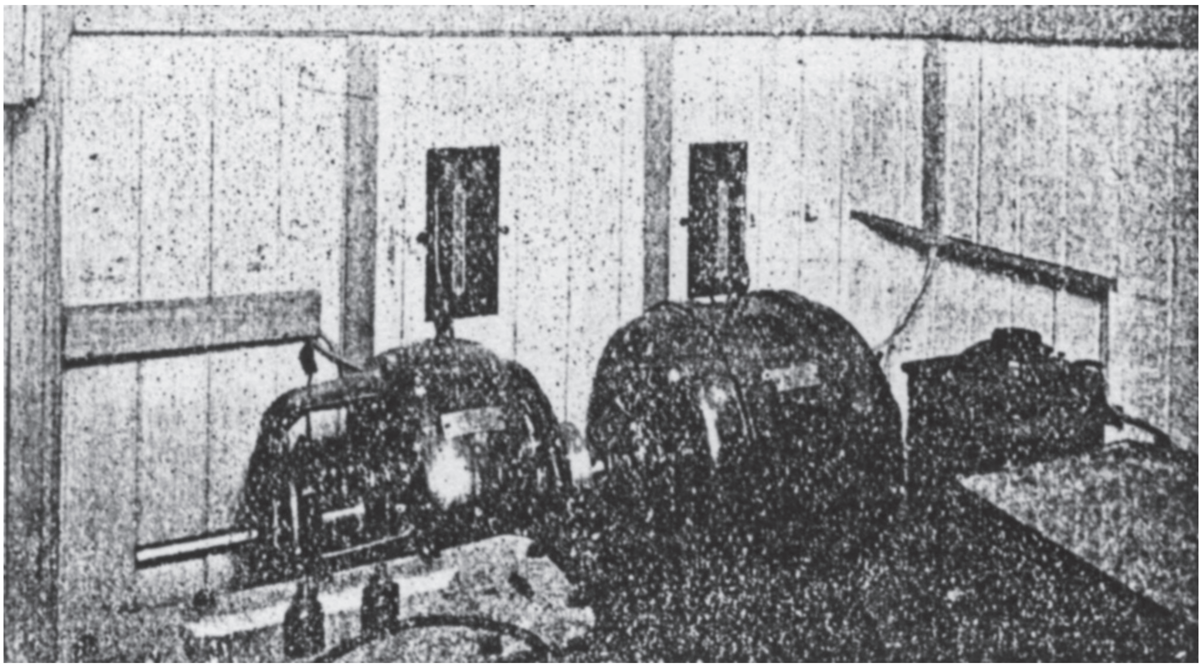


Fig. 24-29 **Motor-Generator Set on *Olympic*** – The fitting of the Marconi motor-generator set in *Olympic*'s Silent Room during construction. The protective shunts are seen mounted to the tongue-and-groove bulkhead behind. The bare shaft sticking out of the alternator has not yet received its teak box containing the rotary spark disc. *(*The Electrician*/Authors' collection)*

Swiss commutator

The main condenser-controlling device was called a 'Swiss commutator'. It consisted of two brass tubes of square cross-section, each having five holes drilled through them. They were supported on a horizontal baseboard which carried five tubes of similar cross-section, placed horizontally with their axes at right angles

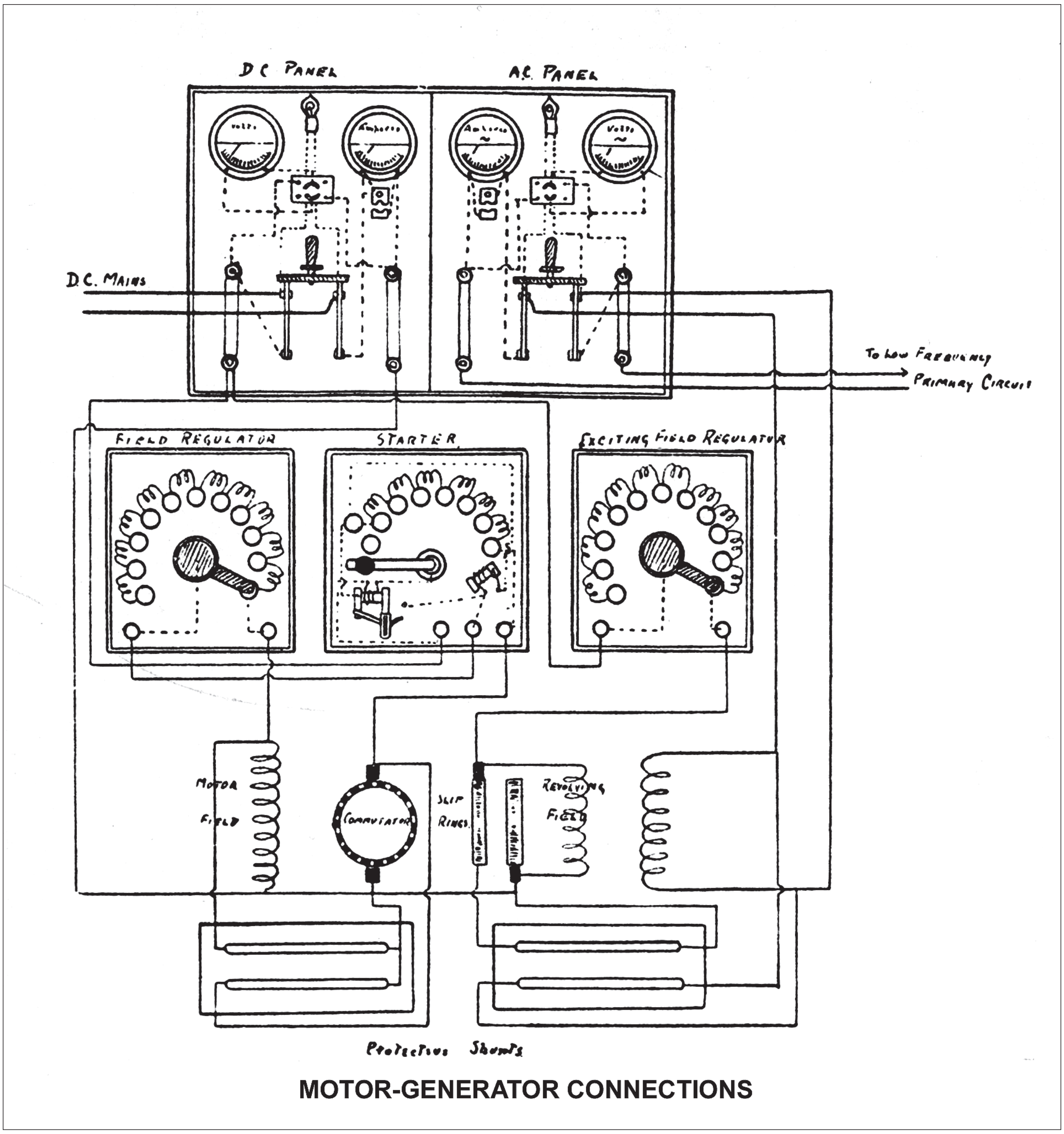

D C PANEL
A.C. PANEL
Volts
Amperes
Amperes
Volts
D.C. MAINS
To Low Frequency
Primary Circuit
FIELD REGULATOR
STARTER
EXCITING FIELD REGULATOR
Motor Field
Commutator
Slip Rings
Revolving Field
Protective Shunts
MOTOR-GENERATOR CONNECTIONS

Fig. 24-30 **Diagram of Motor-Generator Connections** – A schematic diagram of the motor-generator connections shown in the image of *Olympic*'s Silent Room.

to the aforementioned tubes, and about 2in below them. The lower bars had terminal screws at certain points, as well as the two upper tubes. The four condensers were connected to these terminals. The terminals of the upper tubes were connected to the leads from the air-core chokes and also to the rest of the closed oscillatory circuit. Brass plugs or pins were used to connect the upper and lower tubes of the Swiss commutator. The pins could be placed in certain configurations (the four condensers in series, in parallel and two groups of two in series, the two groups being connected to the circuit in parallel) to obtain different variations of the four condensers.

The connections between the condensers and the commutator were made with stout copper strips of ample surface; ebonite strips were placed between the bars of the commutator and between the copper connecting strips to prevent sparking. Spark points of flat brass were fitted to the condenser terminals and set so that any excessive voltage would break down the air resistance in preference to breaking down the condenser.

High-frequency inductance

A high-frequency inductance consisting of a heavy copper spiral of square cross-section took the place of the trombone or sliding inductance used in the 1½kW set. A highly insulated ebonite handle, supplied with a flexible copper contact at the end of a brass screw of the same pitch as the spiral, was used to vary the amount of inductance in the circuit, thus enabling any adjustment of wavelength to be made between those lengths given by the different condenser values.

Disc discharger

A synchronous disc discharger replaced the fixed type of discharger used in the 1½kW set. It consisted of a 10in diameter steel disc, supplied with 16 copper studs on either face near its periphery, which was rotated between two fixed copper electrodes. The disc was mounted on a continuation of the motor-generator shaft by means of an insulating rubber coupling, the disc and fixed electrodes being enclosed in a thick teak box so constructed as to deaden the sound as much as possible. Heavily insulated ebonite handles projected through two sides of the box, by means of which the distance between the fixed electrodes and the copper studs on the disc could be adjusted in order to adjust the length of the sparking gaps; in order to allow for the movement of the stationary electrodes they were connected through heavy ebonite brushes to two external terminals by means of thick flexible cable. The external terminals were connected to the closed oscillatory circuit in the same way that the ordinary fixed discharger was connected on the earlier 1½kW set.

By means of this type of discharger the circuit could be adjusted so the condenser spark discharge took place at absolutely regular intervals, with the result that a very musical note was emitted. With the fixed discharger, the note could only be a pure one if the voltage remained absolutely constant. If the voltage dropped too low, the spark would frequently miss and if it rose too high, an arcing spark was produced.

The disc discharger could be adjusted so that the spark took place at each half-period. If the voltage was a little lower at the end of one half-period than at the end of another, the spark took place when the moving electrode had approached a little nearer the fixed ones and vice-versa, but due to the speed of rotation and the small vibration in distance required, the slight delay or advance of the discharge had little effect in spoiling the purity of the note.

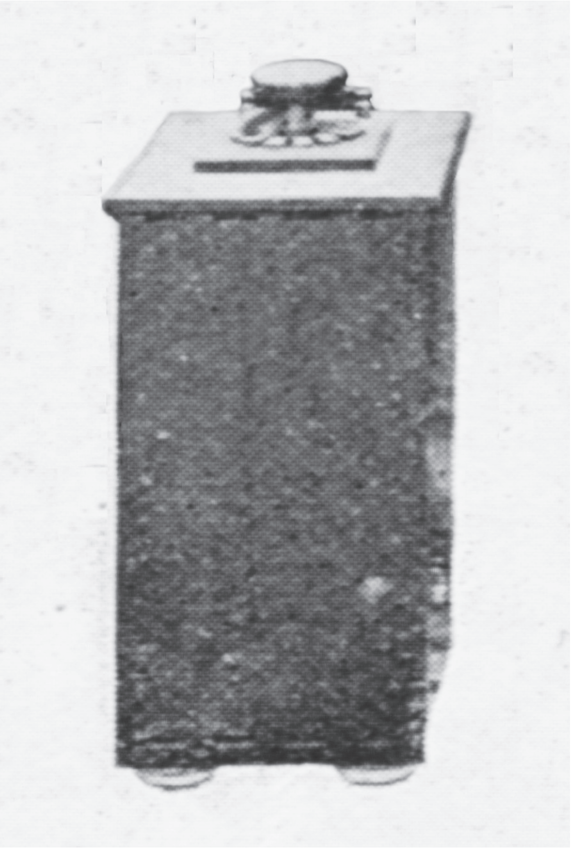


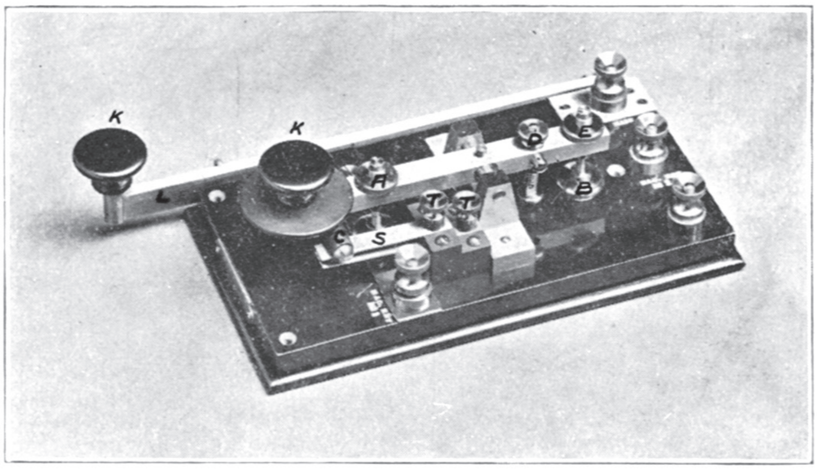
Fig. 24-31 **Low-Frequency Iron-Core Inductance.**

Because the spark took place at a fixed time with respect to the voltage of the alternator and as the relationship varied for different arrangements of condenser, a phase adjustment was provided. The rubber coupling between the machine and the discharger was fixed between two flanges on the ends of the two shafts. Quadrant slots were cut in the disc flange, which enabled the disc to be fixed so that a moving stud was exactly between the fixed electrodes for the different values of lag or lead. Bolts through the quadrant-slots and a scale marked in phase degrees on the periphery of the disc-coupling flange enabled any adjustment to be made easily and rapidly.

The spark frequency had nothing to do with the oscillation frequency; the latter depended on the oscillation constant of the circuit, while the former depended on the speed of the disc and the number of studs employed. If a disc carrying sixteen studs rotated at a speed of 21,000RPM, there would be 33,600 sparks per minute, or 560 per second.

The transmitting jigger

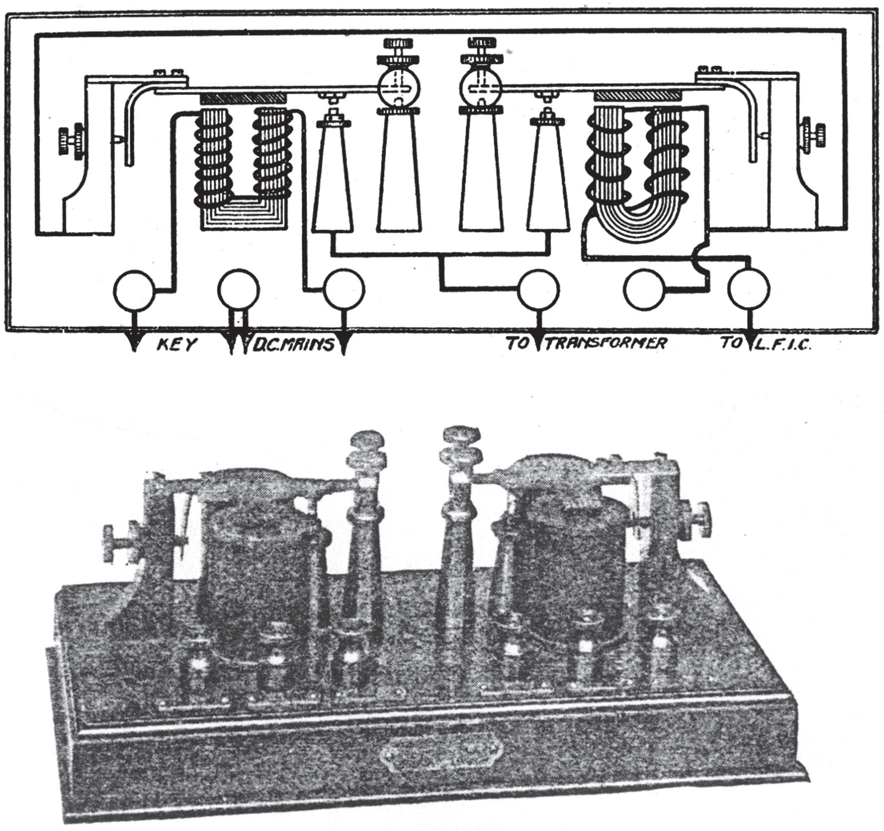
The primary was wound with one turn, built up of sixty-three strands of No.20 copper wire, each strand



MANIPULATING KEY.

A, Contact adjusting Screw.—B, Back Stop.—C, Ebonite Cam for adjusting Short Circuit Contacts.—D, Spring adjusting Screw.—E, Back adjusting Screw.—K, Ebonite Knobs.—L, Side Lever.—S, Telephone Short Circuiting Springs.—T, Short Circuiting Terminals.

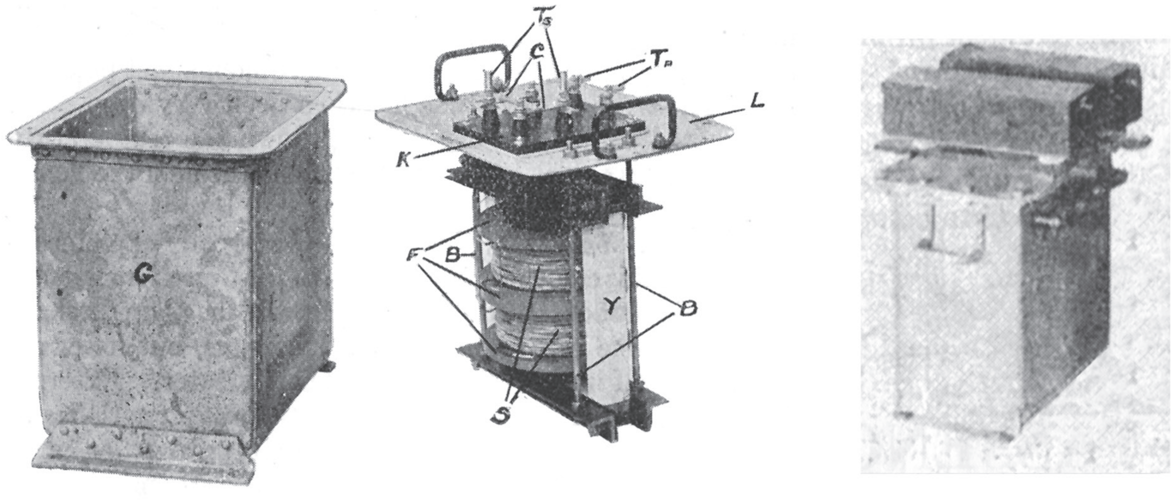
Fig. 24-32 **Manipulating Key**.



DOUBLE MAGNETIC RELAY KEY

Fig. 24-33 **Double Relay Key**.

being cotton-insulated and the whole impregnated with paraffin wax and shellacked. It was wound around a wooden former, square in shape. The two ends were brought through heavy ebonite bushes through the bottom of the teak box in which it was contained and were soldered into terminal sockets. One lead was connected to the second end of the high-frequency spiral inductance and the other end was connected to



MARCONI TANK TRANSFORMER, CLOSED IRON CORE, OIL COOLED.

B, Transformer Supporting Bolts.—C, Secondary Change-over Straps.—F, Fibre Plate.—G, Galvanised Tank.—K, Kalanite Terminal Plate.—L, Galvanised Lid.—S, Secondary Sections.—Tp, Primary Terminals.—Ts, Secondary Plug Sckets.—Y, Yoke.

Fig. 24-34 **Transformer** – The Marconi galvanized tank transformer. At left, a period illustration showing a design used for both the 1½- and 5kW systems, however, *Titanic*'s was a variation of this design, similar to what is shown in the image to the right. The wooden boxes at the top of the image at right contain aircore choke coils which are discussed under the high-tension circuit. The difference between the two designs shown here is the placement of the exterior connection terminals. On *Titanic*'s transformer there were four connections on the front side with two brass straps. This, depending on how they were attached to the connections, would put the transformer in parallel or series.

the main condenser, thus completing the oscillatory circuit. The standard wavelengths used on board ship were 300 and 600 meters, but with adjustment of the close oscillatory circuit, wavelengths up to 1100 meters could be achieved.

The Open Oscillatory or ‘Radiating’ Circuit

This was the last circuit in connection with the transmitting apparatus. It consisted of the secondary winding of the jigger, an aerial-tuning inductance, an earth-arrester spark gap and a tuning lamp.

The jigger secondary

This consisted of eight turns of cable, consisting in turn of twenty-one strands of No.20 copper wire, each strand cotton-covered, and the whole mounted within a teak box. Taps to eight brass sockets placed on the face of the box in which the secondary was contained were taken through ebonite insulating bushes. For all practical purposes there were seven turns, each one being slightly more than one full turn in order that the taps were suitably disposed round the face of the container. The box containing the secondary was made to slide over the box containing the primary by a handle and screw fitting, thus permitting a variation of the coupling. The scale on the primary box gave a rough indication of the percentage coupling, but did not give a definite reading, as the coupling depended to a certain extent on the aerial used, the inductance of the radiating circuit being distributed throughout its length.

Aerial-tuning inductance

Twenty turns of cable, consisting in turn of nineteen strands of No.20 wire, vulcanized and braided, were wound around a square wooden form. Taps were brought from various points to eight brass sockets arranged on the face of the teak enclosure through ebonite insulating bushes. It was possible to adjust to any number of turns (marked on the face of the box) from 1 to 19 by taking connections from the appropriate sockets. As in the case of the jigger secondary, there was really one more turn than was accounted for by the numbers marked on the face of the enclosure. This ensured that all the taps occurred at a fraction over the complete turn, so that they did not come directly under each other. As there was no variable condenser in the open oscillatory circuit, the oscillating constant could only be varied by altering the inductance and this piece of apparatus was designed for such an operation. A long aerial had a larger capacity and inductance than a short one, so that less of this aerial tuning inductance was required in connection with the long than with the short aerial for the production of the same wavelength.[9]

The earth-arrester spark gap

This device consisted of two brass circular plates separated by a distance of one-hundredth of an inch from each other by means of a mica disk, each plate being supplied with four terminal nuts. The upper plate was kept in a rigid position with respect to the lower one by means of a brass pin fixed in the center of the latter, which passed through an ebonite-bushed hole in the center of the former, a lock nut being screwed on to the upper extremity of the pin. A circular groove was made in each plate coinciding with the edge of the mica disc to prevent sparking and burning at the edge of the mica.

The tuning lamp

This consisted of a four-volt lamp in series with an adjustable inductance coil mounted on a teak base. The induction coil was wound with 8ft of bare No.16 copper wire on a grooved boxwood core. One end of the winding was free and the other end was connected to a terminal on the baseboard. A second terminal was connected to one of the lamp contacts, the other contact being connected to a pivoted brass arm, the extreme end of which would be moved over the copper wire inductance.

The lower end of the aerial was connected by means of a flexible lead of seventy strands of No.40 copper wire, one end of which was attached by a wood-handled brass plug to the required socket of the aerial tuning inductance. A second flexible connection with a similar plug at either end connected the aerial-tuning inductance to the secondary of the jigger, the earth terminal of which was connected by means of the same type of flexible cable to the upper plate of the earth-arrester. The lower plate of the earth arrester was connected by means of 7/16 India-rubber vulcanized braided cable to an earth bolt. This latter was a hexagonal brass bar which was reduced and screwed at each end and supplied with nuts and washers. One end of it was screwed and tapped into a hole in the steel bulkhead of the ship. The length of the bolt enabled it to pass through the thickness of the wood lining of the cabin and still leave the inner end accessible for making the required connection to the earth-arrester. The two terminals on the baseboard of the tuning lamp were connected to two points about 6ft apart on the wire connecting the earth terminal of the jigger to the upper plate of the earth-arrester.

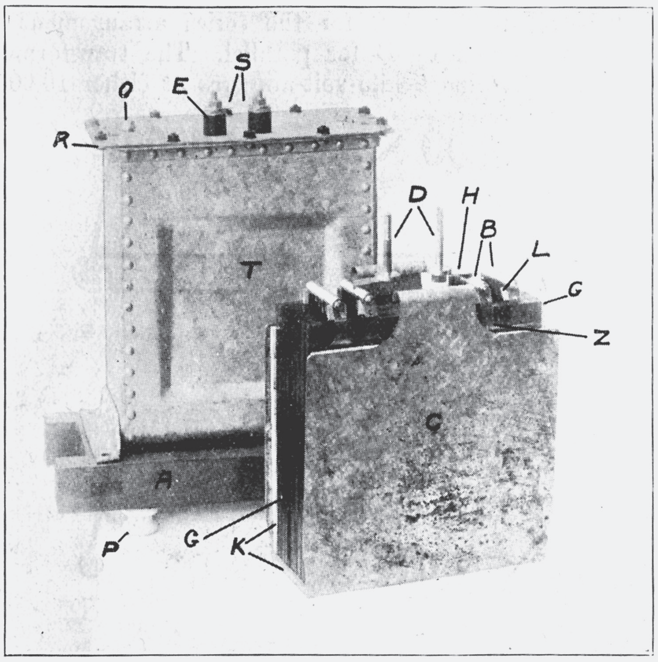
Short-wave condenser

Because *Titanic*'s aerials were so long, their natural frequency did not admit a wavelength of 300 meters without taking out too many turns of the jigger secondary. To compensate for this, a condenser was connected between its lower extremity of the aerial and the upper plate of a separate earth-arrester spark gap. By suitably fixing the value of the condenser, the aerial circuit could be tuned to a 300-meter wave. Next, the jigger secondary itself could be tuned with the aid of another condenser to give a 300-meter wave. This second condenser was made equal to the first, and the circuit adjusted to 300 meters by using more or less inductance. It was better, however, to use the jigger secondary, neither more or less and to adjust by alternating the second condenser. The two 300-meter circuits thus obtained could be joined together by putting the two condensers in parallel and connecting the aerial to earth. The complex circuit thus formed would still radiate a 300-meter wave, which would be excited by the action of the jigger primary on the jigger secondary.

THE RECEIVING CIRCUIT

The Magnetic detector or 'maggie'

This instrument consisted of two ebonite discs grooved around their peripheries and mounted on a spindle forming part of a clockwork driving mechanism contained in the body of the instrument and mounted on a brass plate capable of sliding along a bed piece. The adjustment was made by turning a screw to put the necessary tension on a continuous band of stranded soft iron wire. This band was formed by seventy strands of No.40 single silk-covered iron wire twisted into the form of a small rope and was rotated by the clockwork at the rate of about 1.6 meters per minute. This band passed through the centers of two sets of coils with primaries and secondaries. The ends of these coils were connected to four terminals on each side of the instrument, the secondary winding being connected to the inner pair of terminals in each case. Between these two sets of coil, a wooden block carried four horseshoe magnets, two on either side with their like poles positioned adjacent to



THE DOUBLE PLATE, WHOLE PLATE CONDENSER.

A, Tank Stand.—B, Brass Lug Washers.—C, Galvanised Iron Cradle.—D, Terminal Bolts.—E, Ebonite Bushed Terminals.—G, Glass Plates.—H, Copper Connecting Strip.—K, Oiled Wood and Cork Packing.—L, Leather Stools.—O, Oil-filling Hole.—P, Porcelain Feet.—R, Rubber Packing.—S, Spark Guard Points.—T, Galvanised Tank.—Z, Zinc Sheets.

Fig. 24-35 **Condenser**.

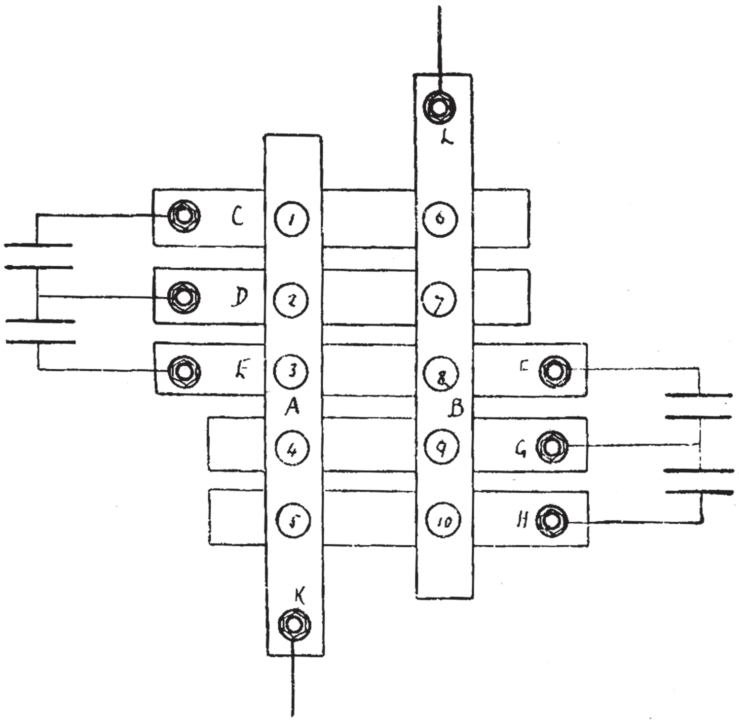


FIG 1. SWISS COMMUTATOR FOR 4 CONDENSERS.

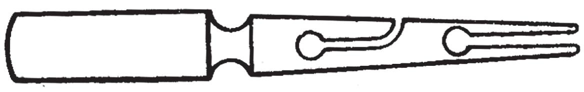
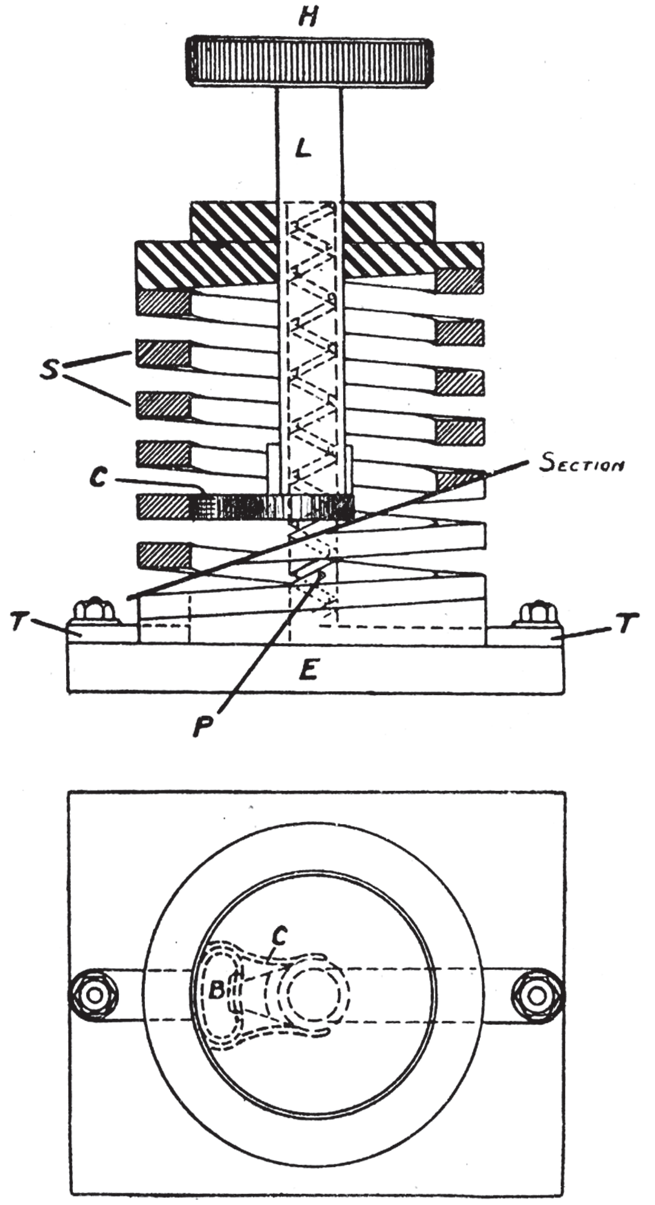


FIG 2.

Fig. 24-36 **Swiss Commutator** – Fig. 1: *A* and *B* – hollow copper bars of square cross-section; *C*, *D*, *E*, *F*, *G* and *H* – terminal screws; *L* and *K* – terminals connected to the air-core chokes and closed oscillatory circuit. Fig. 2: Plug for Swiss commutator – used to connect the upper and lower bars. If two of these plugs were to be fitted through the holes marked 1 and 10 into the corresponding holes beneath, the condensers would be joined in parallel. If the plugs were placed through the holes marked 1, 7, 3, 9 and 5, or through the holes marked 6, 2, 8, 4 and 10, the four condensers would be connected in parallel. If plugs were placed through the holes marked 6, 3 and 10, the condensers would be arranged in two groups of two in series, the two groups being connected to the circuit in parallel. In order to create the 600-meter wave, the condensers were configured in parallel. For the 300-meter wave, the condensers and transformer were configured in series. As a side note, an extra condenser was provided in order to shorten the capacity of the aerial to achieve this shorter wave.



H.F. Spiral Inductance
5 K.W.

B, Bronze Brush Spring.—C, Copper Braid.—E, Ebonite Base.—H, Ebonite Handle.—L, Brass Tube.—P, Screwed Brass Pillar.—S, Copper Spiral.—T, Brass Terminal Blocks.

Fig. 24-37 **Spiral Inductance**.

each other. This arrangement resulted in a slight hissing sound being produced in the telephones whenever the band was moving. If the magnets were rearranged, this hissing or breathing effect was eliminated though, at the same time, the sensitivity of the receiver was slightly lessened. The arrangement was a matter of personal choice for the operators.

A handle was provided for winding up the clockwork, which would drive the band for an hour and three-quarters for one winding-up. The clockwork was designed for both even and silent running. A brass knob provided means of stopping or starting the clockwork.

Only one side of the detector coils was used at a time, the second set of coils and magnets being provided as a stand-by in case of a breakdown in the other set. The primary terminals were connected by means of a bare No. 10 copper wire to the terminals marked 'DETECTOR' on the multiple tuner.

The maggie, although less sensitive than some other forms of detector, possessed a number of advances

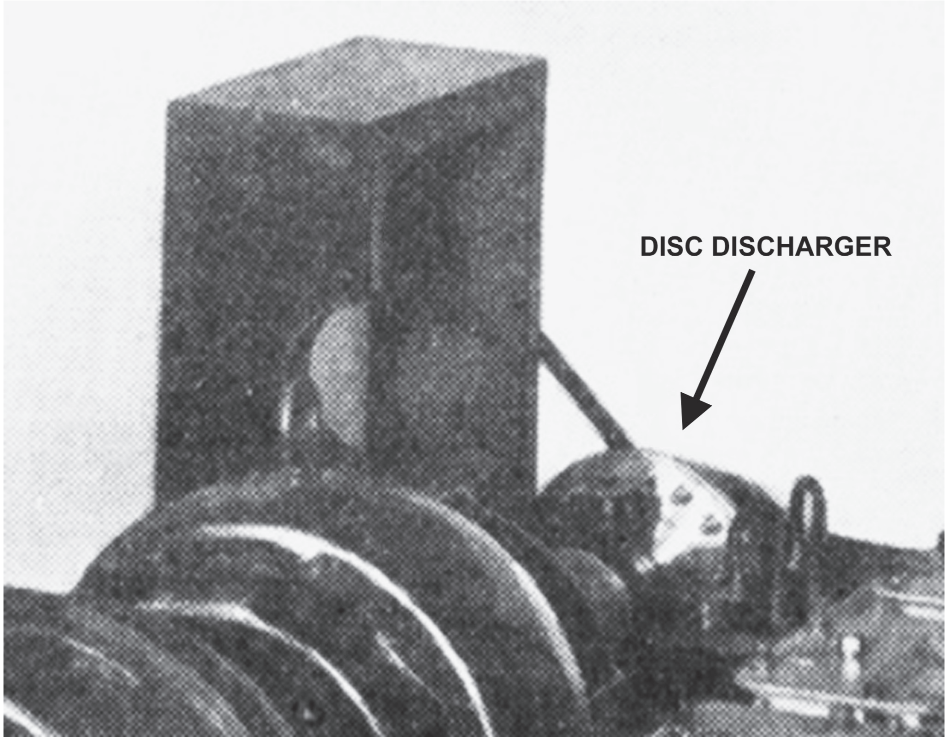


Fig. 24-38 **Disc Discharger** – In this enlargement can be seen the synchronous disc discharger of the type used on *Titanic*. This was contained in a teak box.

which were of practical value. Prominent among these was that once properly adjusted, it would remain in that state indefinitely. It was sturdy in construction and well suited for shipboard use.

The multiple tuner

This instrument contained the variable inductance and capacity for the aerial receiving circuit, the whole of an intermediate circuit and the variable inductance and capacity for the detector tuning circuit. The inductance coils were contained in a teak box with an ebonite top and front. On the top were three disc condensers (one for each circuit), a two way change-over switch and a micrometer spark gap. To the left-hand side of the front of the instrument was an ebonite handle carrying a brass arm, arranged to rotate over a set of brass studs set in the form of a circle, which enabled the inductance in the aerial circuit to be adjusted. To the right of this was another handle connected by means of ebonite coupling strips to three brass arms so that these brass arms could be moved simultaneously over three sets of brass stops. This enabled proportionate adjustments to be made in each of the three circuits with a single movement. This assembly was called the tuning switch. Each of the two handles was calibrated, the aerial inductance being marked in microhenrys, and the tuning switch showing the limits of the receivable wavelengths on the respective stops. On the right-hand end of the instrument, a third ebonite handle called the intensifier handle was mounted, marked in degrees through one quadrant on its periphery. This handle was used to vary the relative positions of the inductances in the intermediate circuit with respect to the inductances in the aerial and detector circuits, or to vary the coupling between the circuits.

The aerial circuit consisted of the aerial, the variable inductance, the variable condenser, the variable inducing inductance and a connection to earth. From the junction of the aerial and the inductance, a lead was taken to a micrometer spark gap to earth. From the junction of the inductance and the variable condenser, a coil of high inductance value afforded a second path to earth. The use of the gap and inductive shunt was to prevent the accumulation of a heavy static charge on the aerial. Small charges leaked to earth through the shunt coil and heavy sudden charges jumped the spark-gap to earth, this being the path of less resistance, or impedance, than the path through the oscillatory circuit. The inclusion of these circuits in the apparatus was necessary to protect the aerial tuning condenser from being broken down and the inductance coils from having their insulation damaged.

The intermediate circuit consisted of the two fixed inductances joined in parallel across the variable condenser. The detector circuits consisted of the fixed inductance, the variable condenser and the primary winding of the magnetic detector, which connected to the tuner at terminals.

Variation of the handles could achieve the needed effects in way of receiving waves. Thus, reception of short and long waves could be achieved by rotating the ebonite tuning switch handle on the right-hand side of the front

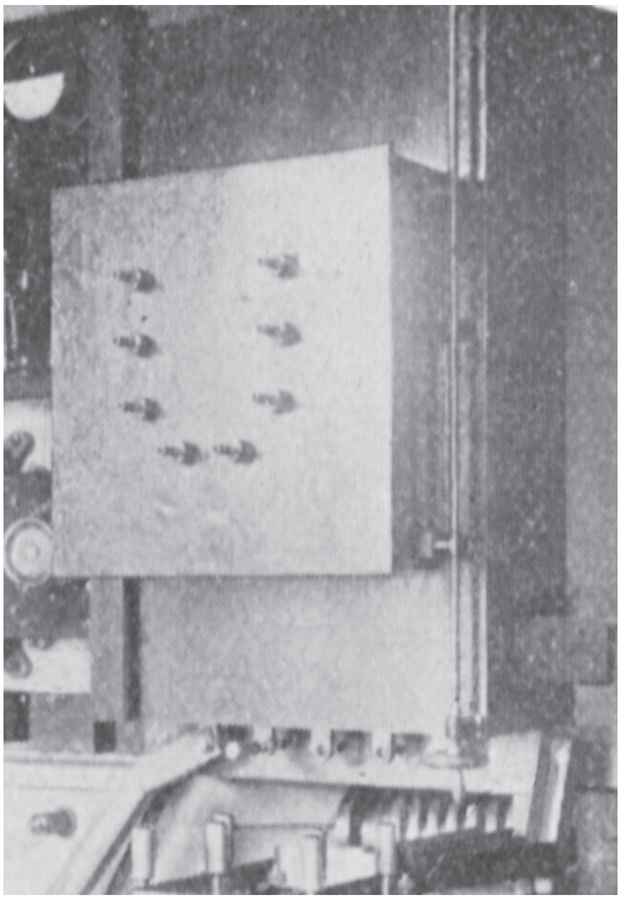


Fig. 24-39 **Primary and Secondary Jigger.**

of the box. A variation of the aerial-tuning inductance handle on the left side of the box, or the intensifier handle on the right side, allowed for different taps or alterations of internal coils. The switch on the top of the instrument was used to change over from a 'stand-by' position, when waves of widely varying length were audible, to a 'tune' position. This was done when it was desired to cut out signals other than those of the wavelength whose reception was required. When the instrument was set to 'stand-by', the magnetic detector was direct in the aerial circuit, and the operation of throwing the switch over placed it in the detector circuit.

The tuner was designed for a wavelength of from 80 to 2,600 meters. The higher wavelengths were utilized to receive news from shore stations for the shipboard newspapers. There were two terminals marked 'DETECTOR' on the topside of the box, which were connected to the ends of the primary of the magnetic detector. The other two terminals, also on the top of the instrument, were marked 'AERIAL' and 'EARTH' and were connected by means of 2½-ampere flexible wire, to the upper and lower plates respectively, of the earth-arrester gap. The received currents, being extremely weak, were unable to break down the air resistance of the small gap and run to earth through the whole of the receiving circuit. The introduction of the earth arrester at this point in the circuit was to act as an

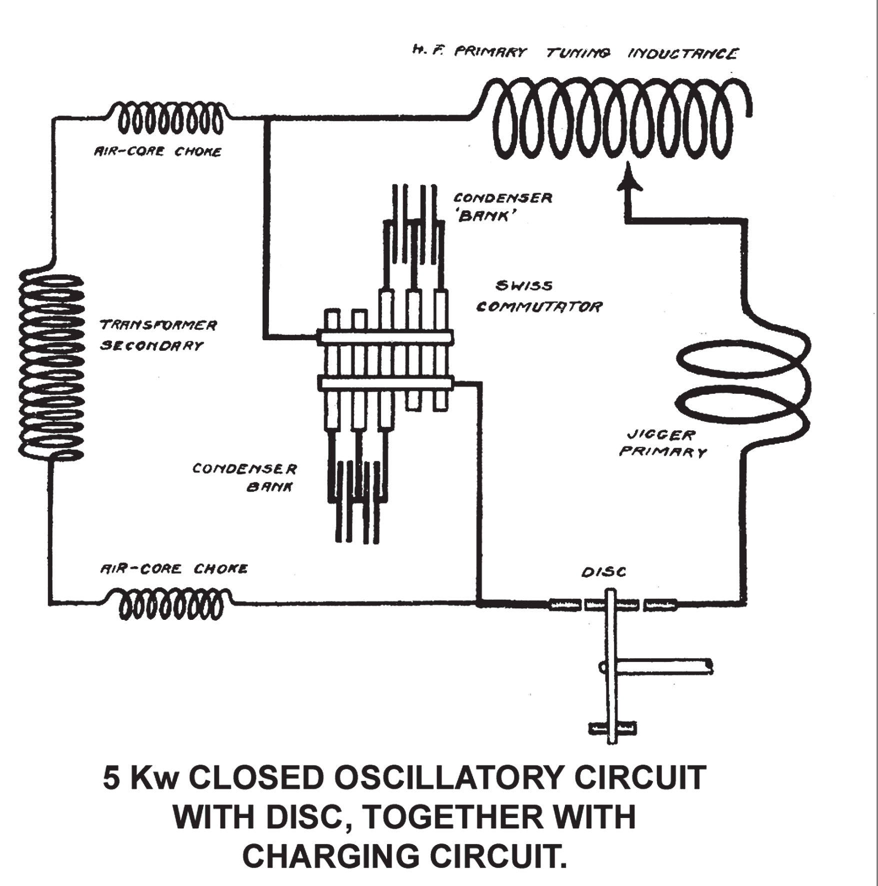
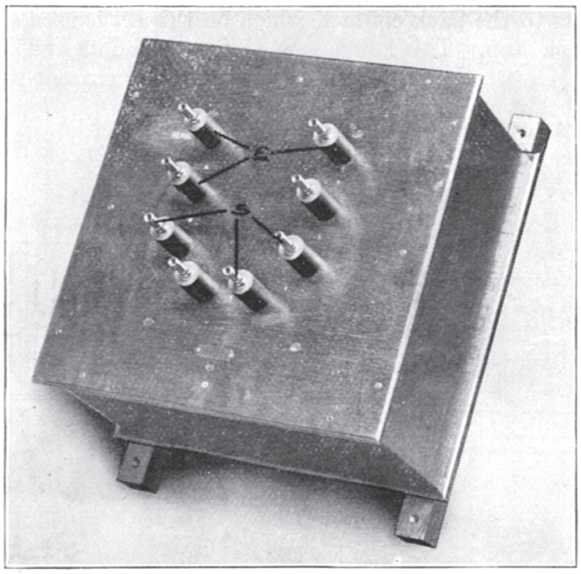
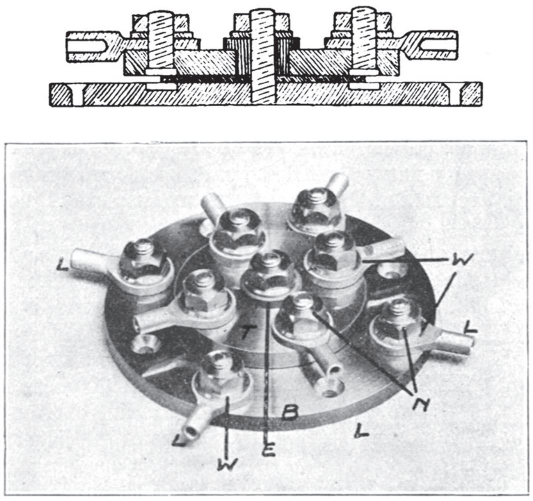

H. F. PRIMARY TUNING INDUCTANCE
AIR-CORE CHOKE
CONDENSER 'BANK'
SWISS COMMUTATOR
TRANSFORMER SECONDARY
JIGGER PRIMARY
CONDENSER BANK
AIR-CORE CHOKE
DISC
5 Kw CLOSED OSCILLATORY CIRCUIT WITH DISC, TOGETHER WITH CHARGING CIRCUIT.

Fig. 24-40 **Closed Oscillatory Circuit** – Brief schematic overview of the Closed Oscillatory circuit with disc discharger.



AERIAL TUNING INDUCTANCE (TRANSMITTING)
E, EBONITE BUSHES. - S, BRASS PLUG SOCKETS

Fig. 24-41 **Aerial-Tuning Inductance**.



EARTH ARRESTER (MICA DISC TYPE)
B, BOTTOM PLATE. E, EBONITE BUSH. L, BRASS LUG.
N, BRASS NUT. T, TOP PLATE. W, BRASS WASHER

Fig. 24-42 **Earth-Arrester Spark Gap**.

automatic switch, obviating the necessity for a separate switch for the purpose of changing over from sending to receiving.

The valve receiver

Titanic's wireless set was provided with the latest type of valve receiver, installed as a stand-by. This device would have been used in place of the magnetic detector and multiple tuner if needed. The valve receiver was considerably more sensitive than the magnetic detector and multiple tuner, but required decidedly more skillful handling. Among its limitations was that it had a more limited range of wavelengths than the multiple tuner and magnetic detector. Because of its design, the tuning condenser had to be kept as small as possible, thus effecting the variance of the wavelengths obtainable within limits. The longest wavelength obtainable was about 700 to 800 meters, making it useless to attempt to adjust to shore stations such as Poldhu, Arlington, Eiffel Tower[10] or other long-wave stations.

In this receiver, a tuner and detector were combined in one instrument, the tuning arrangements being similar to those of the multiple tuner. The detector consisted of a Fleming valve, which depended upon the unilateral conductivity of the space surrounding a hot filament in an exhausted bulb. The valve consisted of a small glass bulb containing a filament resembling that of an electric lamp, around which was placed a metal cylinder. The cylinder was connected to a lead that passed through the wall of the bulb, and the filament was connected to two contacts in the bayonet holder.

When the filament was glowing and the sheath was cold, it was possible to pass a small current from the filament to the sheath, but no current could pass in the opposite direction. It was, therefore, called a 'valve'. In practice, owing to the unavoidable warming-up of the sheath, a negligibly small current did pass back to the filament.

Photographic evidence indicates that the configuration of the valves of *Titanic*'s set were the type that included additional screens of copper gauze covering the outside of the glass bulb and making electrical contact with the metal cap surrounding the filament contacts. This screen protected the valve from heavy spark discharges in the neighborhood, which appeared to have the effect of fixing a charge on the glass walls of the valve, rendering it temporarily insensitive.

A valve was placed in each of two sockets fitted on top of the instrument. Although two valves were fitted, only one was used at a time, a small two-way switch bringing either one or the other into use. On the left-hand side of the receiver were two variable resistances, the switch to change over from one valve to the other, and a rheostat and potentiometer for the valve circuit.

The three adjustable tuning circuits contained in the valve receiver were of the aerial circuit, intermediate circuit and the valve circuit. A 'stand-by' switch cut out the intermediate circuit, but still left an inductive coupling to the valve circuit. This differed from the circuit arrangement of the multiple tuner, which threw the magnetic detector directly into the aerial circuit on 'stand-by'. The top of the instrument held the round condensers to actuate adjustments in the aerial and intermediate circuits.

The aerial circuit included a variable inductance, a variable condenser and an inducing coil. The intermediate circuit was of the same type as that used on the multiple tuner. It was inserted between the aerial and valve circuits when the switch was on the 'tune' side. The valve filament circuit consisted of the 6-volt accumulator battery, the filament and a variable resistance by which the glow of the filament was regulated. A resistance of fine wire was joined across the battery and was supplied with a sliding contact forming a potentiometer. The valve rectifying circuit was outlined by the letters T, A, P, F and S. The telephones were shunted by a condenser and the slider on a potentiometer adjusted the fixed potentials between the filament and the sheath. Finally, the jigger secondary and a small variable tuning condenser called a 'Double Billie' made up the valve oscillatory circuit which supplied the variable potential between the filament and sheath and generated by the incoming signals.

The battery supplied with the unit was actually two batteries joined together. Each battery consisted of three cells in celluloid containers permanently connected and fitted into a polished teak box, which was mounted separately and was located on a shelf above the operating table. The box had a plug socket by means of which connection was made either to the charging switchboard or to the receiver. The batteries were of 40 ampere-hour capacity and required a normal charging current of 2.5 amps, the specific gravity of the acid used being 1.190.

The charging board

A small charging board was provided for use in connection with the valve accumulator batteries. It consisted of two bayonet lamp sockets, a small moving-iron voltmeter with a range from 0 to 10 volts fitted with a small push button on its casing, two plug sockets and terminals for two fuses; all were mounted on a slate slab.

The plug sockets consisted of two concentric brass rings insulated from each other, the center ring being attached to the negative lead in both cases. Four plugs were supplied by means of which the various connections could be made. Two of these plugs were attached to the ends of a length of twin flexible wire, the inner contacts being connected to the ends of that part of the flexible wire, the wire being covered with black braid. This ensured that when the two plugs were placed in the socket on the accumulator box and the socket located directly across from the voltmeter, respectively, the negative plates of the accumulators would be properly connected to the negative charging main because the negative plates were connected to the inner ring of the socket in the box. A third plug was attached to one end of another piece of twin flexible wire; the other ends were connected to the positive and negative mains on the marine switchboard (to be addressed later).

Two 50-candlepower carbon-filament lamps were placed in the sockets to regulate the charging current to the required amount. Depressing the push-button on the voltmeter gave a reading that indicated when the cells were charged. When current was required for the valve, it was only necessary to remove the charging plug and insert the valve plug. Two separate accumulator batteries were provided so that while one was being used in connection with the valve, the other could be placed on charge.

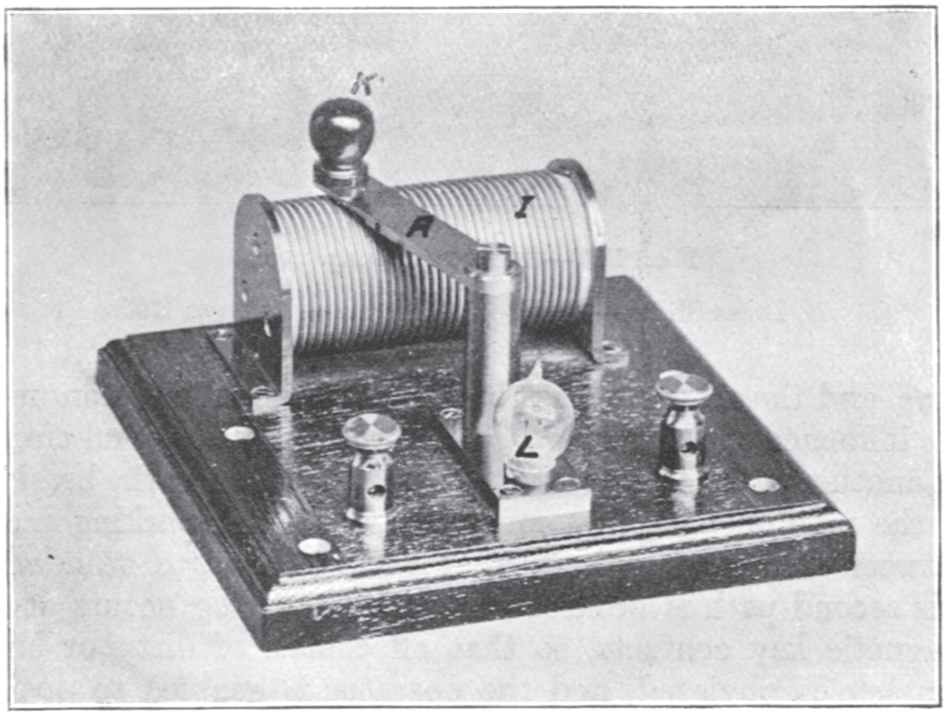
The telephone condenser

The telephone condenser consisted of sheets of tin foil used as conductors, alternate sheets being separated from each other by a mica dielectric. The condenser was divided into three parts, varying amounts being placed in the circuit by means of brass plugs and sockets. Five brass blocks were secured to the ebonite top of a teak box. Three condenser groups of .055, .110 and .220 microfarads, respectively, were fixed by means of paraffin wax in slots cut in a wooden lock. The top of the box was fitted with brass blocks with brass plugs, by means of which connections could be made to select a number of variations of condenser. The capacity was large in comparison to the outside dimensions of the instrument. Because the condenser had to withstand only low currents, the required distance between the conductors and the thickness of the dielectric was small, thus allowing for a large number of sheets providing a large area in a small place.

The terminals of this condenser were connected to the secondary terminals of the magnetic detector by means of 2½-ampere flexible wire. Its use was to alter the tone of the signals in the telephone to suit the operator and to adjust the telephones to their most sensitive condition.

The telephones

The telephone (headset) receivers in use at a wireless station could be divided into two classes, high resistance and low resistance. The accepted method of referring to telephones in terms of their resistance was found



TUNING LAMP

A, BRASS CONTACT ARM. I, COPPER INDUCTANCE COIL.
K, EBONITE KNOB. L, 4-VOLT LAMP

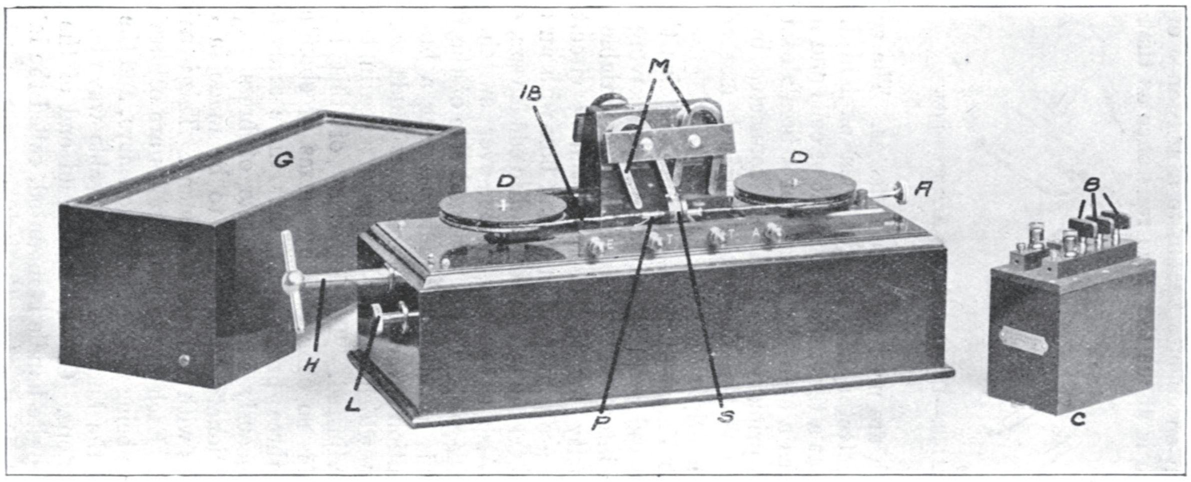
Fig. 24-43 **Tuning Lamp**.

unfavorable as it was not the actual resistance that determined the usefulness of a telephone, but the number of turns of wire around the pole pieces. The aim of the manufacturer was to obtain the greatest magnetic effect with the given current from the detector. With this, the telephones included any number of turns of wire and variations of wire thicknesses. Practice dictated that to obtain the best results, the resistance of the telephone headpiece was to be approximately equal to that of the particular detector used.

With very high-resistance detectors, of which certain forms of the Fleming valve were examples, it was preferable to use a telephone transformer with a high-resistance primary in circuit with the detector and a low-resistance secondary in circuit with the telephones. Such an arrangement was of particular advantage in stations where both magnetic and valve detectors were used, as the same pair of telephones could be used with the magnetic detector as with the telephone transformer of the valve detector.

These instruments were connected either to the terminals of the aforementioned condenser or the secondary terminals of the detector. The telephone utilized the basic principle in that the motion of vibrating bodies excites the ear. These phones were instruments capable of producing frequencies between 29 and 20,000 Hz. They consisted of a disc of thin soft iron, varnished to prevent rusting, set into vibration by fluctuations in the intensity of a magnetic field. Magnets were positioned within close proximity of the soft iron. The core of the magnet was permanently magnetized and exercised a force of attraction to the disc. If current was passed through the coil wound round its poles, this force of attraction was increased or decreased according to the direction of the current. If the force was increased, the center of the disc was pulled towards the magnet; if the force was decreased it was released to some extent. If rapid alterations of current or intermittent unidirectional currents were passed through the windings, the disc (or diaphragm) would vibrate. And if the frequency of the vibrations was within the limits stated above, they would be detected as sound by the ear.

The headsets for wireless installations consisted of two ‘watch receivers’ which were connected in series at the ends of a steel or aluminum spring to form the telephone headgear. In the low-resistance telephones used in connection with the magnetic detector, the wire making up the coils of the electromagnets was insulated with silk. Where a much greater number of turns was required, as in the case of the telephones from 2,000 to 8,000 ohms resistance used with a valve receiver, the insulation consisted of a coating of enamel. In the high-resistance telephone, a pair of protective spark points was included. If the current reached a



MAGNETIC DETECTOR AND TELEPHONE CONDENSER
A, ADJUSTING SCREW FOR VARYING TENSION OF IRON BAND. B, TELEPHONE CONDENSER PLUGS. C, TELEPHONE CONDENSER. D, EBONITE DISCS. G, GLASS FRONTED COVER. H, WINDING HANDLE FOR CLOCKWORK. IB, IRON BAND. L, CLOCKWORK CONTROL. M, MAGNET. P, PRIMARY COIL. S, SECONDARY COIL.

Fig. 24-44 **Magnetic Detector**.

value too great for the coil windings, a discharge took place across the points, preventing the coils from being burnt out.

Short-circuiting device

Two leads of 2½-ampere flexible wire were taken from two brass springs fitted with contacts and mounted on the manipulating key, either to the telephone condenser or to the secondary terminals of the magnetic detector. If the main break of the key and the break between the two small contacts were properly adjusted, the latter would short-circuit the telephone just before the condenser in the transmitting circuit discharged, thus preventing loud sounds of the transmitted signals being heard in the telephones. At the same time, it was possible during the intervals between each transmitted dot and dash to detect any effort on the part of the corresponding station to ask a question.

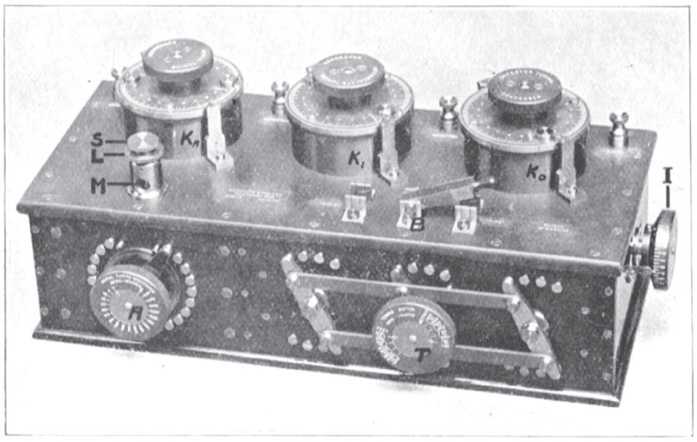
The buzzer circuit

Titanic's receiving circuit was fitted with a testing buzzer. This piece of apparatus was similar to an ordinary electric bell from which the bell and gong had been removed. It was actuated with a small key that caused current to flow through two coils. With an armature being released by electric action, an intermittent current was made to transverse an internal circuit. This current passed from one terminal through another via a non-inductive resistance coil. This resistance was shunted across the buzzer electromagnet windings. A buzzer of this type was called a 'shunted' or 'tuned' buzzer.

The shunted buzzer, manipulating key and a dry cell battery were connected up in series, one end of the series being connected to the Earth terminal of the multiple tuner and the other end being connected to one side of the tuner aerial condenser. When this circuit was set up to its intended condition, it could be used to test or tune the receiving circuit and for tuning the radiating circuit.

The emergency transmitting apparatus

The practice of the Marconi company was to install an auxiliary transmitting set for use in case of breakdown of the main transmitting set; this would have a range of at least eighty nautical miles and be capable of working continuously for at least six hours. This requirement was met in the older installations by fitting a 'Plain Aerial Coil Set' consisting of an accumulator battery, a suitable charging switchboard, a 10in induction coil and a separate manipulating key. Arrangements were made whereby the coil could be quickly placed in connection with the aerial for the production of the plain aerial spark. The advantage of this type of transmission in cases of emergency was that the receiving circuits of stations not strictly in tune were affected by the highly damped waves. It had, however,



MULTIPLE TUNER

A, AERIAL INDUCTANCE HANDLE. B, "STAND BI" CHANGE OVER SWITCH. I, INTENSIFIER HANDLE. K_A, AERIAL CONDENSER. K_I, INTERMEDIATE CONDENSER. K_D, DETECTOR CONDENSER. L, LOCK NUT. M, MICROMETER SPARK GAP. S, ADJUSTING SCREW. T, TUNING SWITCH HANDLE.

Fig. 24-45 **Multiple Tuner**.

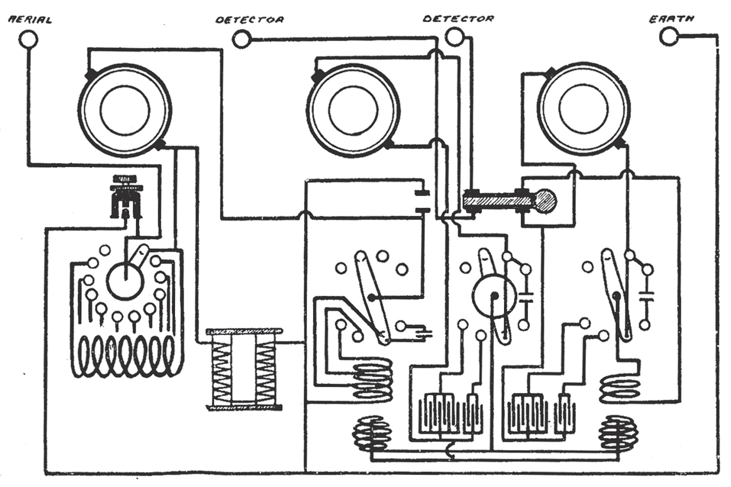
certain disadvantages. The insulation required for the aerial and its fittings was much greater than what was required when the lower-powered sets were used. If the operator allowed the ebonite surface of the lead-in insulator or the surfaces of the aerial mast-head insulators to deteriorate from sunlight, salt water or soot without maintaining them by scraping and oiling or painting with bitumastic, it would be impossible to get a spark until the problem was corrected. An occasional wave breaking over the wireless cabin and lead-in insulator, if the rain cone was not effective, would cause a similar breakdown.

The marine-type switchboard and auxiliary charging switchboard

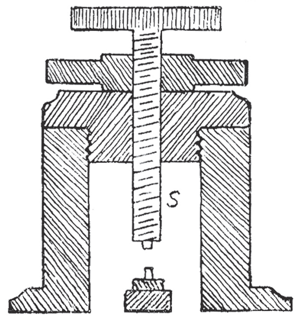
The marine-type switchboard included ten fuses composed of one strand of No.18 bare lead fuse wire wound on a reel, a voltmeter, two light bulbs and switches utilized to achieve particular results. The switchboard was supplied with a single pole three-way and a double-pole, three-way switch. The former was used to connect the coil to the circuit and the latter to connect the accumulators to the ship's main or 'charging dynamos'. Examples of the switch arrangements included: 'ALL OFF', 'CHARGING ACCUMULATORS THROUGH LAMPS 2 AMPS CHARGING RATE', 'LAMPS CUT OUT 12 AMPS CHARGING RATE', 'DISCHARGING ACCUMULATORS 12 AMPS CHARGING RATE', 'WORKING COIL OFF ACCUMULATORS', 'WORKING COIL OFF SHIP'S MAINS' AND 'CHARGING ACCUMULATORS & WORKING COIL OFF ACCUMULATORS'.

The marine switchboard was originally designed for working off the ship's mains at 60 to 80 volts and the accumulators had either to be brought on board fully charged or had to be connected to the coil terminals for a first charge if a large current was required from the ship's mains. Their first charge had to be made at a low rate of 4 amps allowed by the lamp resistance. In order that this board could be used on a more extended range of voltage and that the battery could be able at any time to take a heavy charge from the mains by means of a simple switchover connection, an auxiliary switchboard was supplied. The auxiliary charging switchboard consisted of four resistances and had a single tumbler switch on it indicating either 'CHARGE' OR 'DISCHARGE'. Before changing the position of the switches on the main switchboard, the circuit was to be broken by means of the tumbler switch on the auxiliary switchboard.

When charging the accumulators, the lamps provided on the switchboard panel were to be brought into circuit to check for proper polarity. From time to time, the lamps were to be switched in to see that the right connections continued, and on completing the charge, the mains were to be switched off. The operators were instructed to test polarity occasionally when charging by setting the switches for 2-amp charge. If the lamps burnt brightly, the polarity was correct. If the lamps were dim, the polarity was incorrect. If incorrect, they were to move the double pole switch over to reverse the contacts. Before changing the position of the before mentioned switch, both the tumbler switches were to be placed in the off position.



MULTIPLE TUNER CONNECTIONS



SECTION OF MICROMETER SPARK GAP (MULTIPLE TUNER)

Fig. 24-46 **Schematic Diagram of Multiple Tuner**.

The accumulator battery

The accumulator battery consisted of eight 'chloride' secondary cells. It was used to supply current to the 10in induction coil of the emergency set which had a primary winding of a resistance of about ½ ohm. The ordinary working current taken by this coil was about 8 amps; it was necessary to use eight cells in order to obtain the necessary 16 volts. Each cell contained five negative and four positive plates. The cells were connected to the aforementioned switchboard fitted with resistance- and carbon-filament lamps by which the voltage of the ship's current was regulated to the levels required for charging.

Great care was to be taken to connect the positive pole of the battery to the positive pole of the dynamo when charging. The carbon-filament lamps afforded a simple means of recognizing when such connections had been effected. If the double pole switch was placed in turn in each of its two possible positions, the lamps glowed with two different degrees of intensity. The position of the switch at which the lamps glowed the least brightly was the correct position for charging. The position of the double pole switch determined the direction of the charging current through the battery. The use of the double pole switch made it easy for the operator to change polarity for charging the battery if it was, in fact, required. Simply changing over from one position to the other produced a compensating reversal of the charging current.

The accumulator battery was not used much and the arrangement of the charging resistance was such as to only allow its being charged very slowly. The resistance was 4 ohms and the two 50-candlepower carbon-filament lamps were in parallel with each other and in series with the rest of the charging circuit, allowed a charging current of about 4 amps to pass. The normal charging rate of the battery as given by the maker was 12 amps; in order to keep it well charged, long charges had to be given.

As there were eight cells, the voltmeter with which the switchboard was supplied would give a reading of 8 times 2.6 volts, or 20.8 volts, when the battery was fully charged with the charging current still passing. A short time after the charging current was cut off, the reading of the voltmeter was to be about 17 volts, or approximately 2.1 volts for each cell. In order to maintain battery efficiency, it was advisable to use the battery at least for a short time each day.

The capacity of the battery was 80 ampere-hours by which it was meant that a current of 8 amps could be taken from it for a period of ten hours. If a heavier current was used, the capacity in ampere-hours was less; if a smaller current was used, it increased. The normal charging current

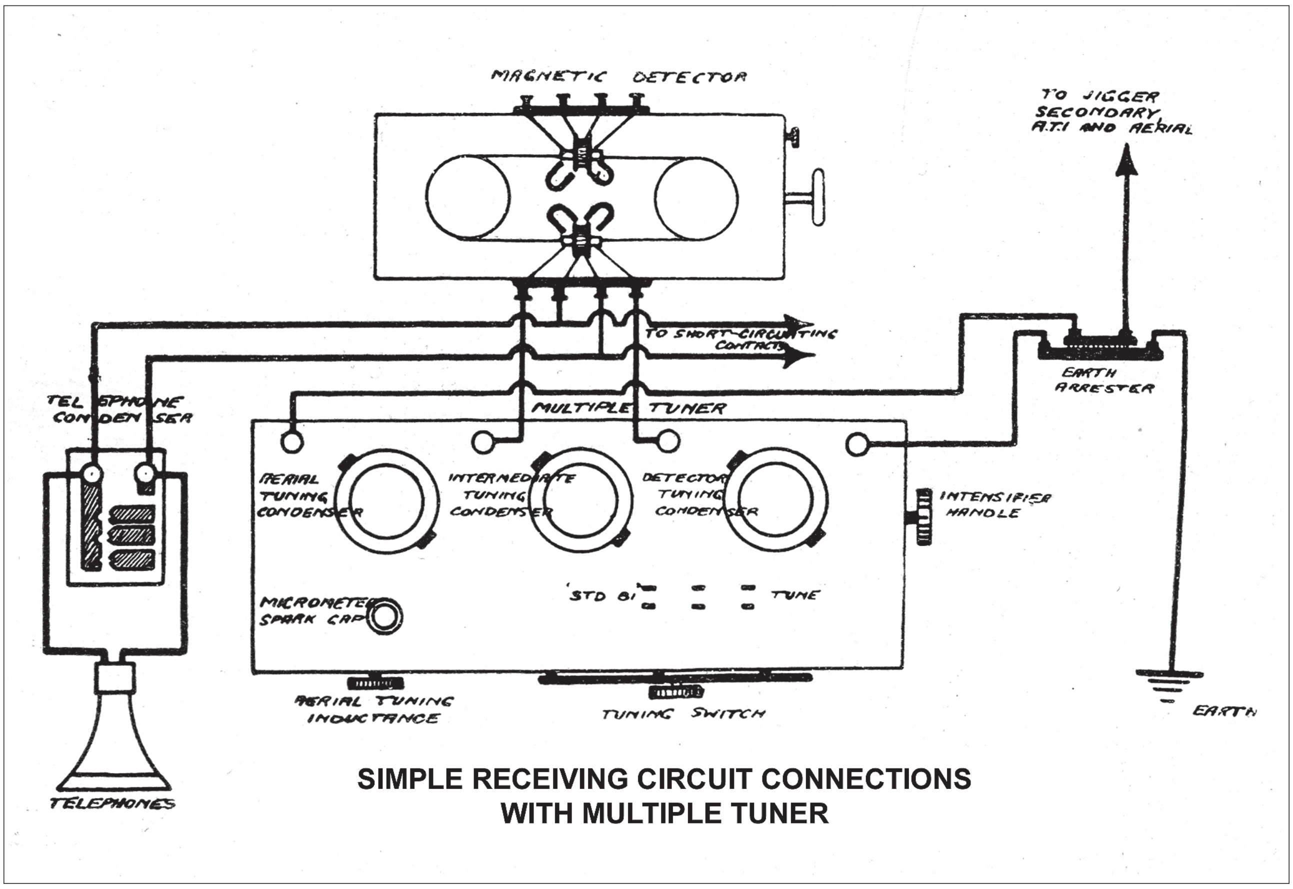

MAGNETIC DETECTOR
TO JIGGER SECONDARY A.T.I AND AERIAL
TO SHORT-CIRCUITING CONTACTS
TELEPHONE CONDENSER
MULTIPLE TUNER
EARTH ARRESTER
AERIAL TUNING CONDENSER
INTERMEDIATE TUNING CONDENSER
DETECTOR TUNING CONDENSER
INTENSIFIER HANDLE
MICROMETER SPARK GAP
STD BI
TUNE
AERIAL TUNING INDUCTANCE
TUNING SWITCH
EARTH
TELEPHONES
SIMPLE RECEIVING CIRCUIT CONNECTIONS
WITH MULTIPLE TUNER

Fig. 24-47 **Multiple Tuner Circuit**.

of 12 amps took about seven-and-a-half hours to fully charge a battery run down to its safety limit.

The 10in induction coil

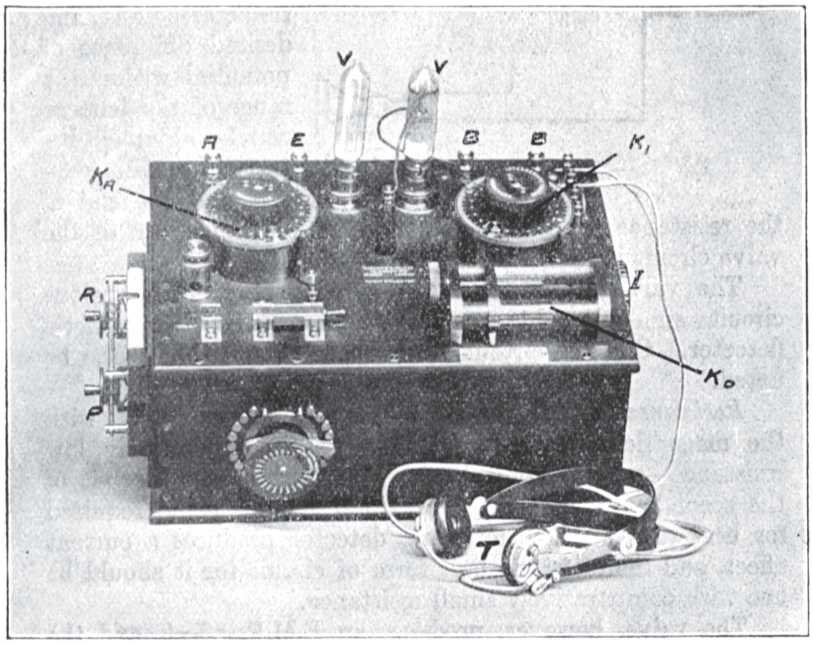
A primary winding of 358 turns of No.12 enameled and braided copper wire was wound over a core of standard soft iron wire. The ends of this winding were brought through the ebonite ends of the casing in which the coils were contained and were supplied with small brass thimbles by means of which connections could be made to two terminals mounted on ebonite supporting blocks. The core and primary winding were contained inside an ebonite tube over which a secondary coil of 54,000 turns of No.34 silk-covered copper wire was wound. This secondary coil was wound in 116 sections, each section being contained in a former of insulated paper. The sections were connected in series, the two extreme ends being connected to two terminals mounted on the ebonite cylinder that enclosed the coils. Brass discharge rods, each fitted with a small ebonite handle at one end and a brass sphere at the other, were mounted on two ebonite supporting pillars and were connected to the terminals through choking coils of fine insulated wire. A hammer break was employed which, when properly adjusted, gave as many as 50 interruptions per second.

Two terminals were connected externally to the source of current supply and internally to the brass supporting pillars of a commutator. The commutator provided a means of altering the direction of the current through the primary winding. An ivory drum was mounted on two brass support pillars, each pillar being connected internally to one of two brass contact pieces placed on opposite sides of the drum. A small ivory handle was fixed at the right-end of the drum, by means of which the latter could be turned on an axis to adjust the direction of the primary current. The handle could also be adjusted to break the current.

In front of the hammer were six terminals mounted in pairs. The two nearest the commutator were connected to the manipulating key, while the other two pairs were fitted with two copper pins and two other terminals were connected internally to a condenser.

The coil condenser

This condenser had a capacity of approximately 2 microfarads, consisting of layers of tin-foil and varnished



VALVE TUNER

A, AERIAL TERMINAL. B, VALVE BATTERY TERMINALS., E, EARTH TERMINAL.,
I, INTENSIFIER HANDLE. KA, AERIAL CONDENSER. KI, INTERMEDIATE CONDENSER.
KD, DETECTOR CONDENSER. P, POTENTIOMETER. R, VALVE RESISTANCE.
T, HIGH RESISTANCE TELEPHONES. V, 4-VOLT VALVES.

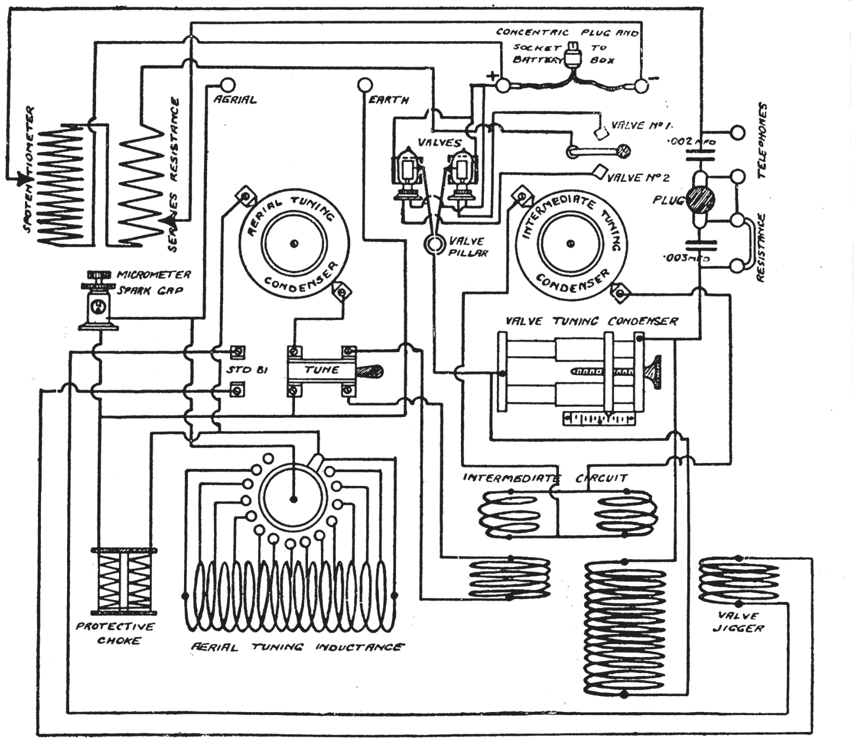
Fig. 24-48 **The Valve Receiver**.

paper. Alternate sheets of foil were connected to one end, the remaining sheets being all connected at the other end. When the key was depressed, a current flowed from the battery through the primary winding and the contacts, and back through the key to the battery. The core of the coil was magnetized and the hammer was attracted. The circuit was thus suddenly broken at the contacts of the hammer. This breaking of the primary circuit produced a self-induced electromagnetic frequency with a tendency to continue the current across the contacts. This electromagnetic force was of so high a value that a vivid spark took place between the gradually-opening contacts unless steps were taken to prevent it. This spark rendered the air between the two contacts conductive and the result was that the primary current continued to flow until the energy of inductance was dissipated. If the primary current was slowly cut off, the induced effect in the secondary was only slight, as the rate of cutting off lines of force was slow.

Immediately after the contacts began to separate, the induced electromagnetic force, instead of sparking across, was taken up to charge the condenser, the primary current being thus interrupted extremely quickly. When the primary circuit was broken, the core lost its magnetism and the hammer was released, contact being once more effected by the hammer spring. If contact was made before the condenser was discharged, the primary current would first have to overcome this back electromagnetic force. As a consequence the rise of current (obstructed at the same time by the self-induction of the primary winding) was comparatively slow and the induced electromagnetic force in the secondary was of a correspondingly low value.

To summarize, the condenser helped to eliminate sparking at the contacts, helped to accelerate the 'break' of the primary circuit and helped to retard the current at the 'make'.

The result was that a much larger induced electromagnetic force was produced at break than at make and, the spark-gap in the secondary circuit being fairly large, an intermittent uni-directional spark took place. The condenser in the circuit also helped to eliminate sparking at the manipulating key contacts. It was generally found in practice that the coil worked better with an extra condenser across the break. Terminals were mounted on the hammer spring base and on the back contact supporting pillar for making connection to an extra condenser which was of the same type and dimensions as that contained in the base of the coil. By means of copper pins, the coil base condenser could be easily cut out of circuit in the event of breakdown.


CONCENTRIC PLUG AND SOCKET TO BATTERY TO BOX
+
−
AERIAL
EARTH
VALVES
VALVE Nº 1
VALVE Nº 2
·002 MFD
·003 MFD
TELEPHONES
PLUG
RESISTANCE
POTENTIOMETER
SERIES RESISTANCE
AERIAL TUNING CONDENSER
VALVE PILLAR
INTERMEDIATE TUNING CONDENSER
MICROMETER SPARK GAP
VALVE TUNING CONDENSER
STD BI
TUNE
INTERMEDIATE CIRCUIT
PROTECTIVE CHOKE
AERIAL TUNING INDUCTANCE
VALVE JIGGER

VALVE TUNER CONNECTIONS

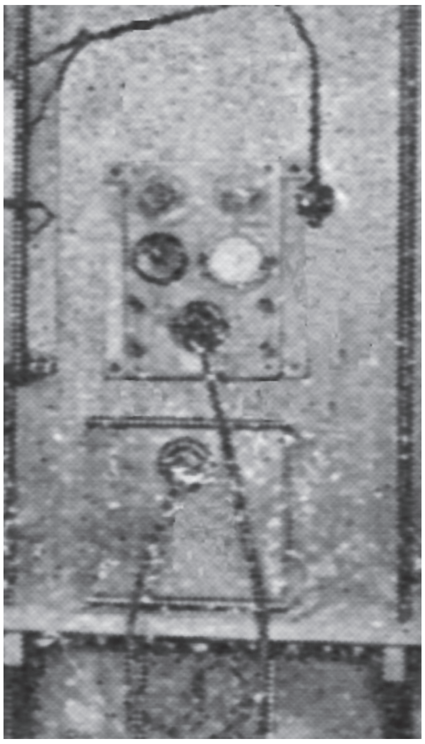
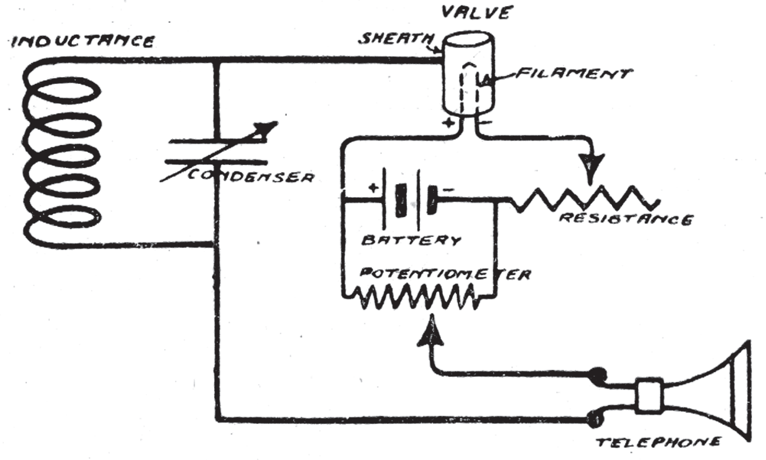


Fig. 24-50 **Charging Board and Batteries**.


VALVE
INDUCTANCE
SHEATH
FILAMENT
CONDENSER
+
−
BATTERY
RESISTANCE
POTENTIOMETER
TELEPHONE

VALVE DETECTOR CIRCUIT

Fig. 24-49 **Schematic Diagram of Valve Receiver**.

Emergency Set manipulating key

The Emergency Set had a key of similar pattern as the main key. As stated earlier, the key was fitted with a slide lever with an ebonite handle used as an emergency switch at the hand of the operator for breaking the circuit if required. A terminal was on the right end of a brass strip running across the key; the other end of this strip formed a socket in which the slide lever rested.

Connections of the Emergency Set

Fig. 24-59 shows the complete connections between the various parts of the Emergency Set. P1 and P2 were wooden pillars, each fitted with brass plug sockets. P1 was permanently connected to the top plate of the earth arrester and P2 to one of the coil discharge rods. The other coil discharge rod was connected to the bottom plate of the arrester. A piece of 20-ampere flexible cable, fitted with a boxwood-and-brass plug at one end and a brass thimble at the other, was used to make connection between the lower end of the aerial to either of these plug sockets. For transmitting, the plug was placed in socket P2, when it was seen that the aerial was connected to one discharge rod, the other rod being connected to earth. The choke coils between the discharge rods and the ends of the coil secondary winding prevented any oscillatory currents from the aerial-earth system rising into the coil and damaging it. When the plug was placed in socket P1, the aerial was disconnected from the coil and connected to the receiving circuit joined across the earth arrester. If the coil were not disconnected from the aerial, a direct path to earth for the received currents would exist through the secondary winding. This was not so much by way of the wire of the winding as by a capacity effect from layer to layer and thence to the primary winding.

When using the emergency set, the connection from the aerial-tuning inductance from the 5kW set, to the lower end of the aerial was removed and replaced by the flexible connection mentioned above.

Tuning of the Transmitting Circuits

Titanic was fitted with a 'Wave Meter' to take the place of utilizing the multiple tuner and magnetic detector for tuning the transmitting circuit. It was a convenient form of wave meter that was manufactured and used by the Marconi company. It consisted of a variable condenser in series with an inductance coil that was usually made in two sections to give a wider range of usefulness. The inductance coil was contained in the lid of a teak box, and the two portions were respectively connected in the circuit by means of a brass plug and sockets. Joined across the condenser was a telephone and carborundum crystal in series, the latter being held in position between two brass upright springs. The instrument was carefully calibrated and a card was supplied giving the wavelengths corresponding to the condenser readings when used with either of the inductance coils.

Wearing the telephones, the person making the measurement walked a short distance from the circuit in which oscillations were being produced and adjusted the condenser until the maximum signal strength was obtained. The most accurate adjustment was obtained when the distance between the observer and the circuit was sufficient to produce signals that were just audible, as then any slight deviation from the correct adjustment would cause them to fail altogether. There was a specific procedure utilized in tuning the low-frequency primary and open and closed oscillatory circuits. These procedures will not be addressed in this text.

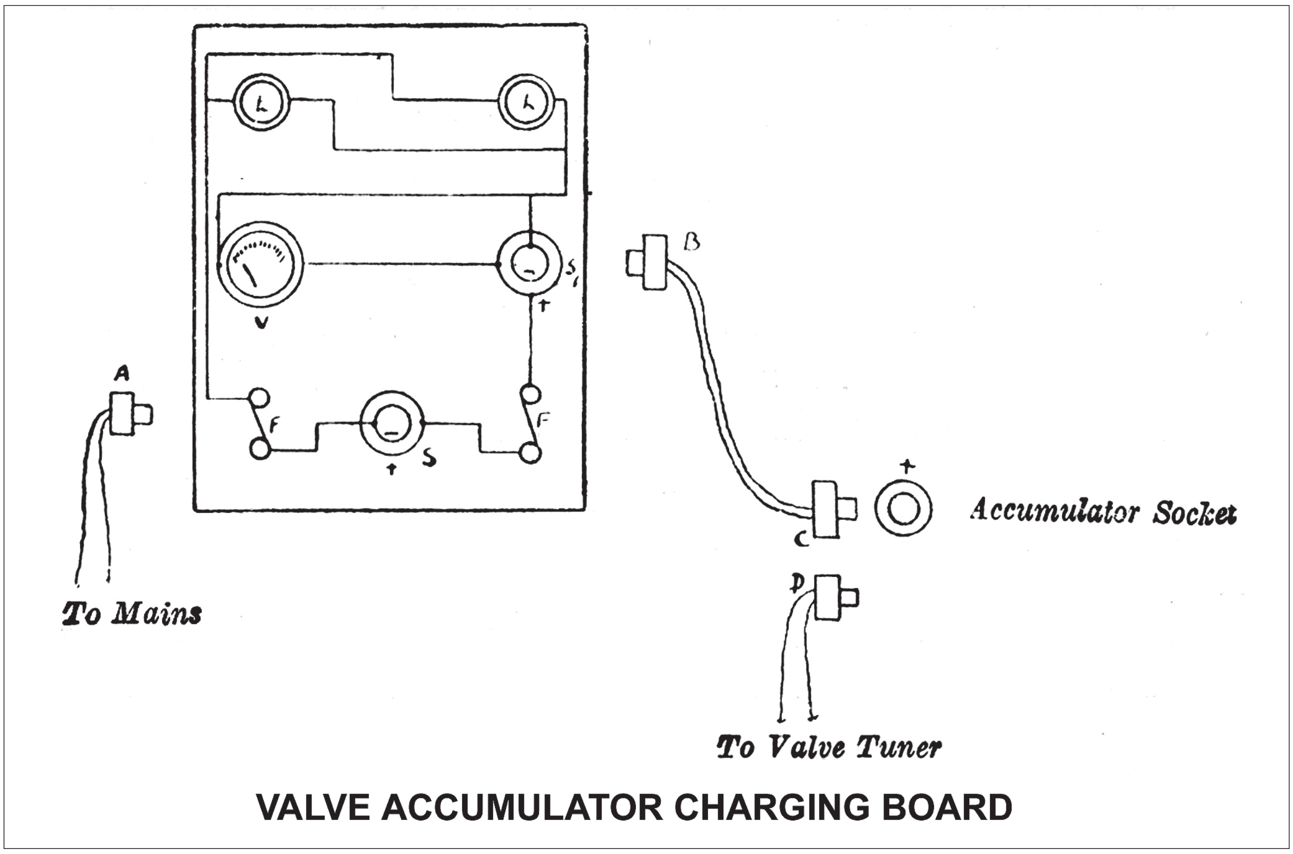
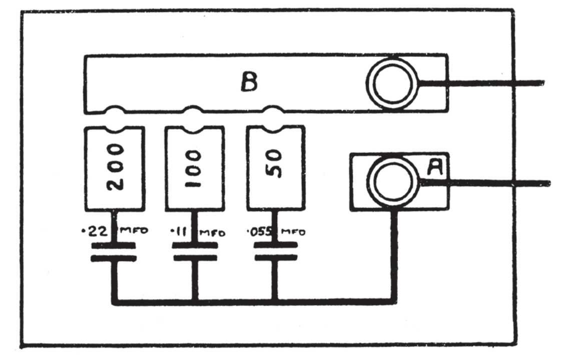
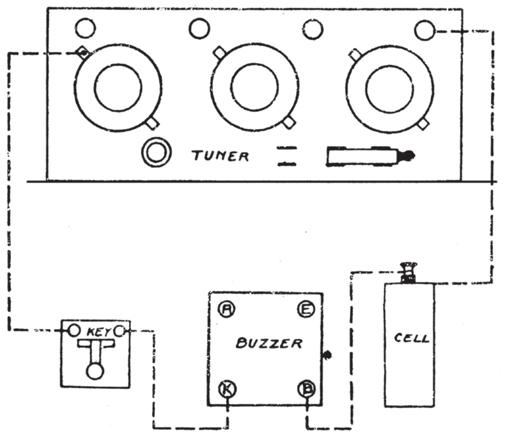


Fig. 24-51 **Valve Accumulator Charging Board** – *L*, Bayonet lamp socket; *V*, Moving-iron voltmeter. *S*, Plug sockets; *F*, Terminals for fuses. If the connections were made between *A* and *S*, *B* and *S1*, and between *C* and the accumulator box, the accumulators would be on charge. Depressing the push-button on the voltmeter gave a reading which indicated when the cells were charged. The fourth plug *D* was attached to one end of another piece of twin flexible wire, carrying two lugs at its other end which were connected to two terminals on the valve tuner. When current was required for the valve it was only necessary to remove the charging plug *C* and to insert the plug *D*. Two separate accumulator batteries were usually provided, so that while one was being used in connection with the valve, the other could be paced on charge.


B
200
100
50
A
·22 MFD
·11 MFD
·055 MFD

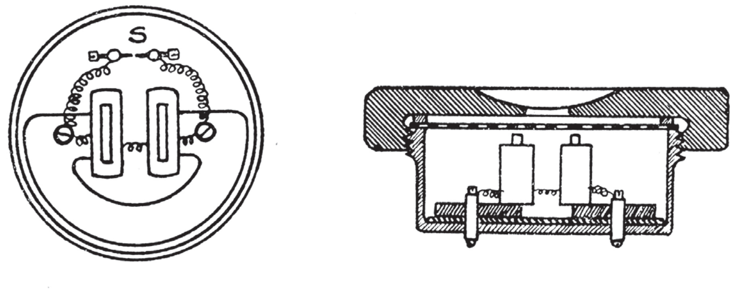
TELEPHONE CONDENSER


TUNER
KEY
R
E
BUZZER
K
B
CELL

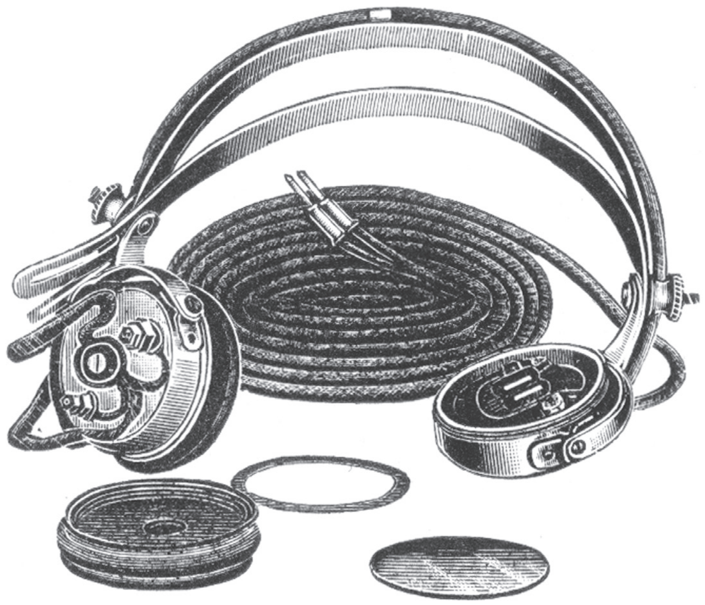
Shunted Buzzer Circuit Connections (External).

Above left Fig. 24-52 **Telephone Condenser Schematic**.

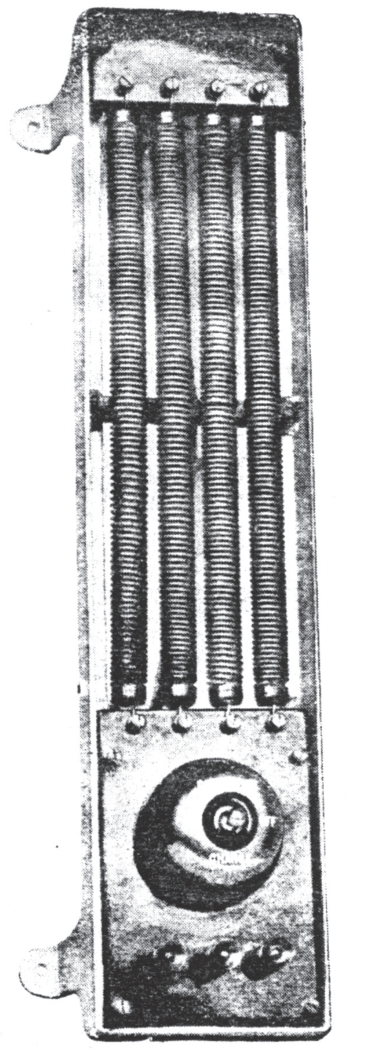
Above right Fig. 24-53 **Testing Buzzer**.



PLAN AND SECTION OF TELEPHONE (WATCH PATTERN)



HEAD PHONE RECEIVER



AUXILIARY PANEL

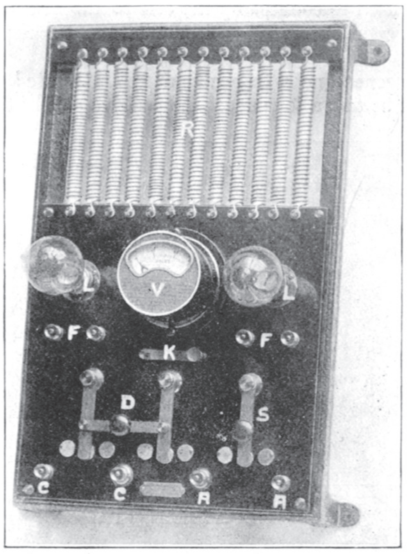
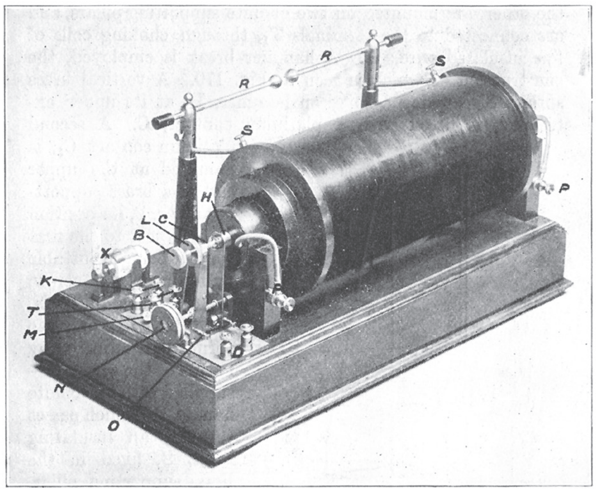

R
V
L
L
F
F
K
D
S
C
C
A
A

FIG. 165.—MARINE TYPE SWITCHBOARD, No. 1.

A, Accumulator Battery Terminals.—C, Coil Circuit Terminals.—D, Double-pole Switch.—F, Fuse Terminals.—K, Voltmeter Key.—L, 50 c.p. Lamps. —R, Charging Resistance.—S, Single-pole Switch.—V, Voltmeter.


R
R
S
S
P
H
L
C
B
X
K
T
M
D
N
O

10″ INDUCTION COIL.

B, Back Contact Adjusting Screw.—C, Platinum Contacts.—D, Main Terminals.—H, Hammer.—K, Manipulating Key Terminals.—L, Lock Nut for Break Adjustment.—M, Condenser Connecting Pin.—N, Tension Adjusting Screw.—O, Terminals for Extra Condenser.—P, Primary Winding Terminals.—R, Discharge Rods.—S, Secondary Winding Terminals.—T, Condenser Terminals.—X, Commutator.

Above left Fig. 24-57 **Marine-Type Switchboard**.

Above right Fig. 24-58 **Induction Coil**.

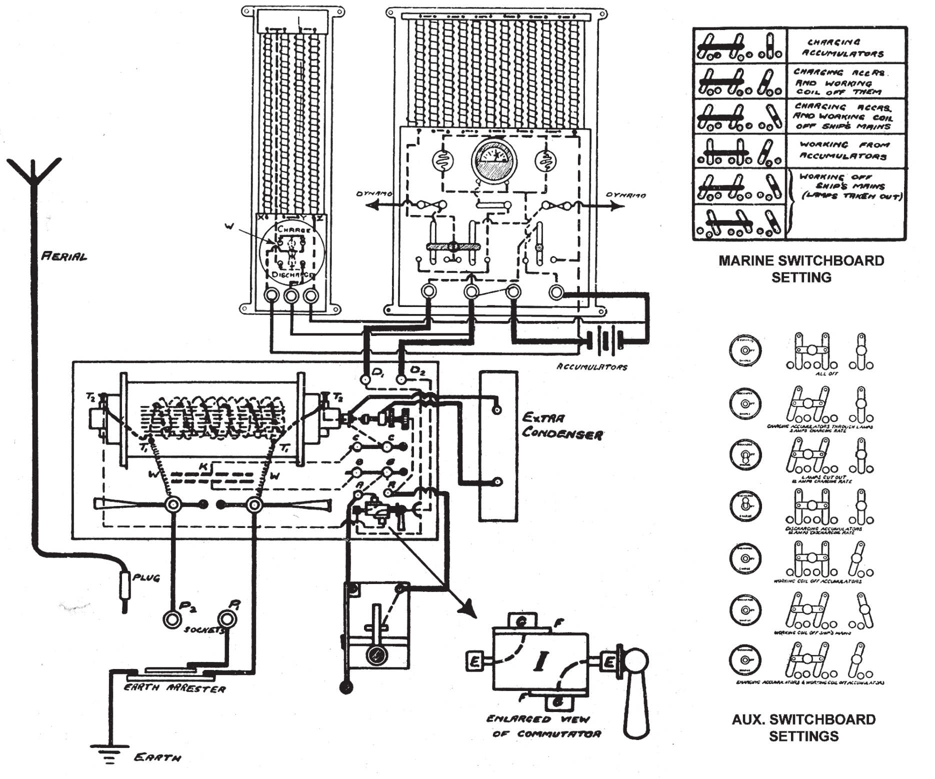
Below Fig. 24-59 **Emergency Gear Schematic**.

Opposite three images:

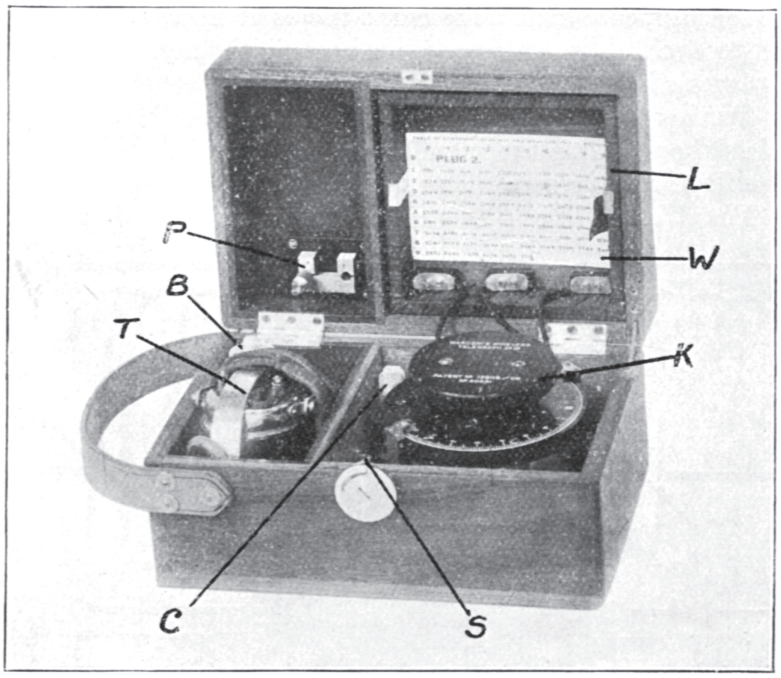
Centre Fig. 24-54 **Telephone Receiver Details**.

Below Fig. 24-55 **Telephones** – Although labeled 'head phone receiver' here, these were properly called 'telephones.'

Right Fig. 24-56 **Auxiliary Panel.**


AERIAL
DYNAMO
DYNAMO
CHARGE
DISCHARGE
ACCUMULATORS
D1
D2
T2
T1
K
W
EXTRA CONDENSER
PLUG
P2
P1
SOCKETS
EARTH ARRESTER
EARTH
E
I
F
ENLARGED VIEW OF COMMUTATOR
CHARGING ACCUMULATORS
CHARGING ACCRS. AND WORKING COIL OFF THEM
CHARGING ACCRS. AND WORKING COIL OFF SHIP'S MAINS
WORKING FROM ACCUMULATORS
WORKING OFF SHIP'S MAINS (LAMPS TAKEN OUT)
MARINE SWITCHBOARD SETTING
ALL OFF
CHARGING ACCUMULATORS THROUGH LAMPS 2 AMPS CHARGING RATE
LAMPS CUT OUT 12 AMPS CHARGING RATE
DISCHARGING ACCUMULATORS 12 AMPS DISCHARGING RATE
WORKING COIL OFF ACCUMULATORS
WORKING COIL OFF SHIP'S MAINS
CHARGING ACCUMULATORS & WORKING COIL OFF ACCUMULATORS
AUX. SWITCHBOARD SETTINGS

PLAIN AERIAL EMERGENCY TRANSMITTING GEAR CONNECTION

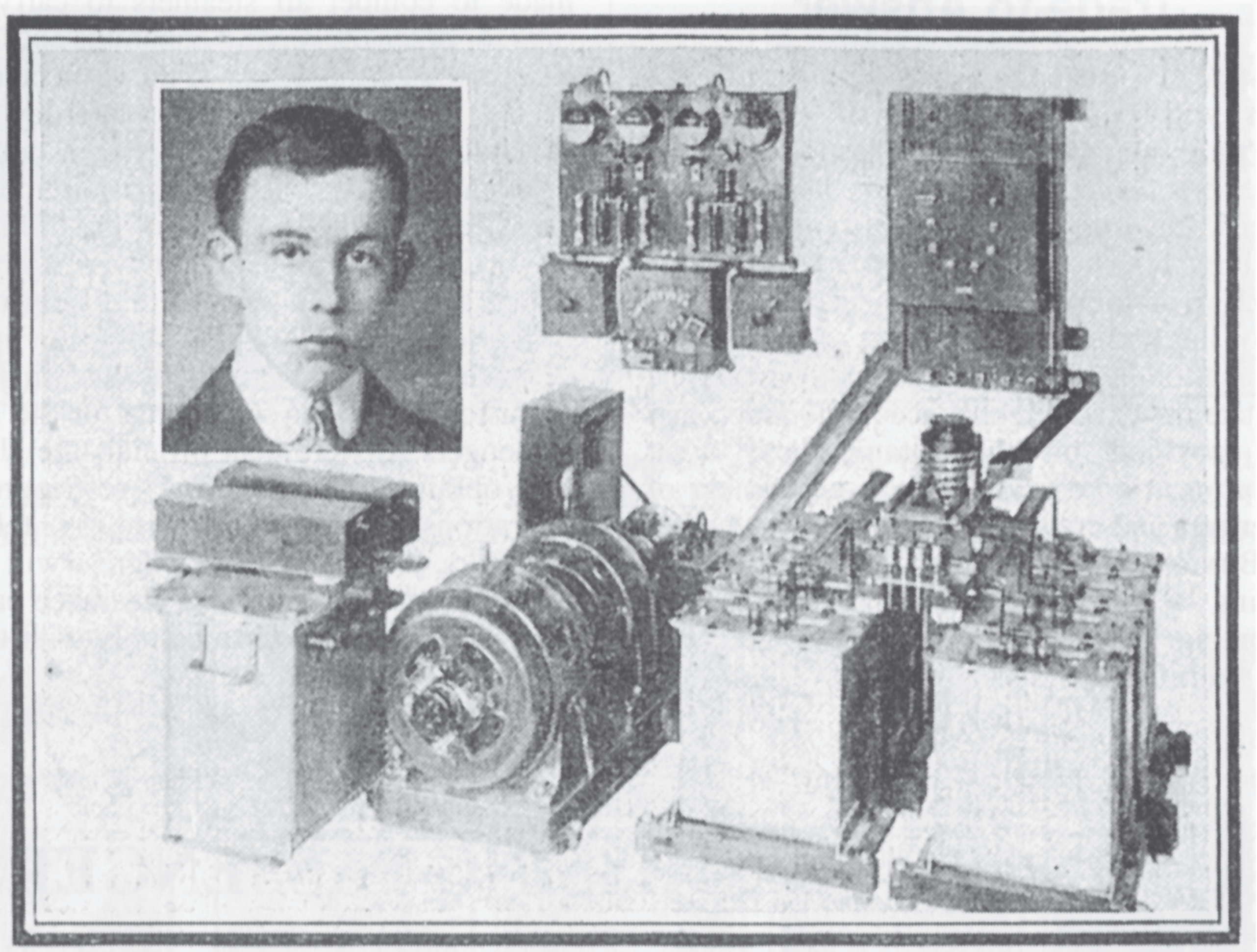


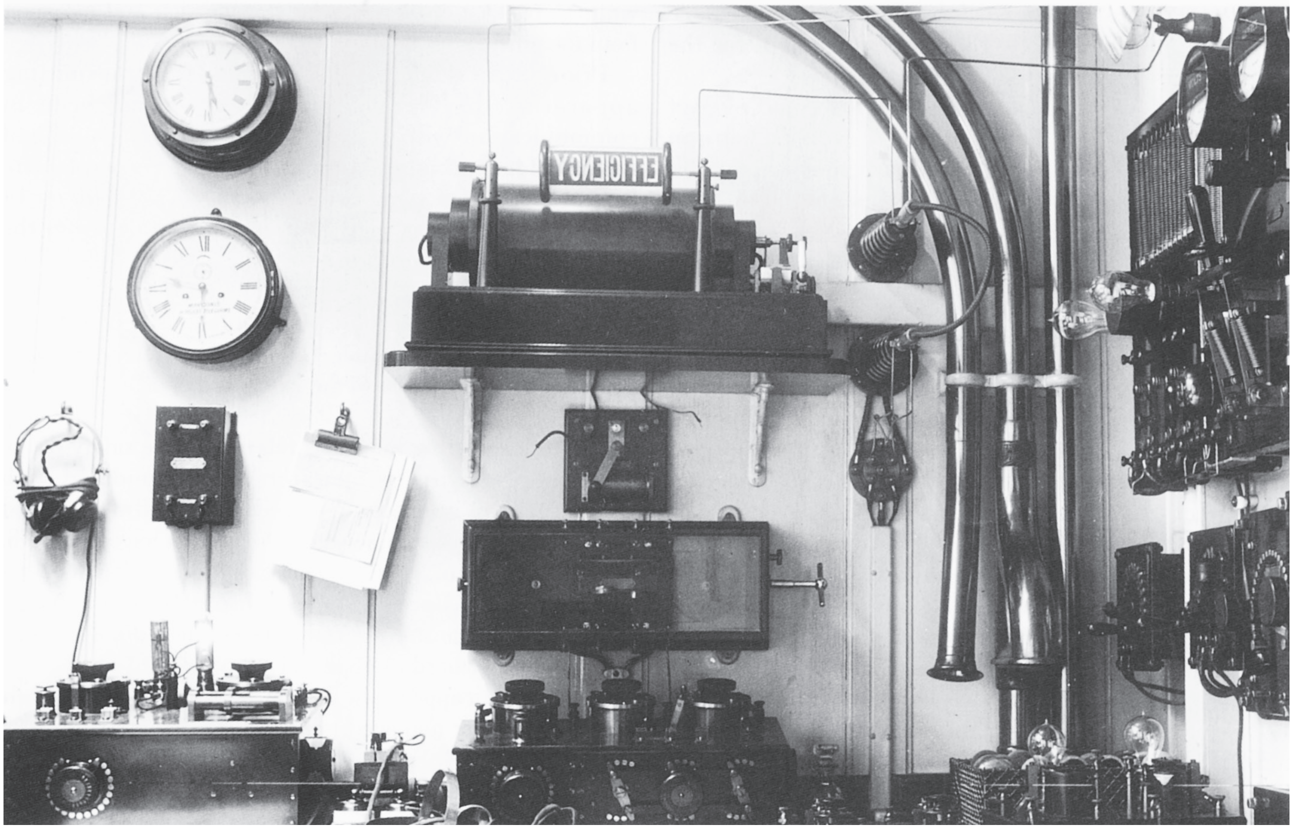
MARCONI WAVE METER No. 2.

B, Crystal Box.—C, Crystal Clip.—K, Condenser.—L, Inductance Coil.—P, Two Range Plug Board.—S, Telephone Sockets.—T, Double Head Telephones.—W, Calibration Chart.

Left Fig. 24-60 **Wave Meter**.

Below Fig. 24-61 **Newspaper Photograph of Wireless Apparatus** – This image from an article in the Daily Sketch shows a Marconi wireless apparatus very similar to that used on *Titanic*. The inset is a photo of *Titanic*'s surviving Marconi operator Harold Bride. The difference between the set seen here and that of *Titanic* is that there are four extra condensers. The illustrations were most likely taken by the newspaper from a period Marconi brochure.





Above Fig. 24-62 **Marconi Operating Room on *Olympic* after Refit** – *Olympic*'s Marconi Operating Room after the 1912-13 refit, in which it was moved to the center of the Officer's Quarters deckhouse just as on *Titanic.* The pneumatic message tubes can bee seen in the corner along with a basket with the message canisters, along with a few extra lamps.

Right Fig. 24-63 **5kW Special Set** – A Marconi set labeled as a '5 kW Special.' This is how it appeared in a period Marconi reference book. It is basically the same as *Titanic*'s set with the exception of the enclosed disc discharger case; *Titanic*'s disc, though, was inside of a teak box.

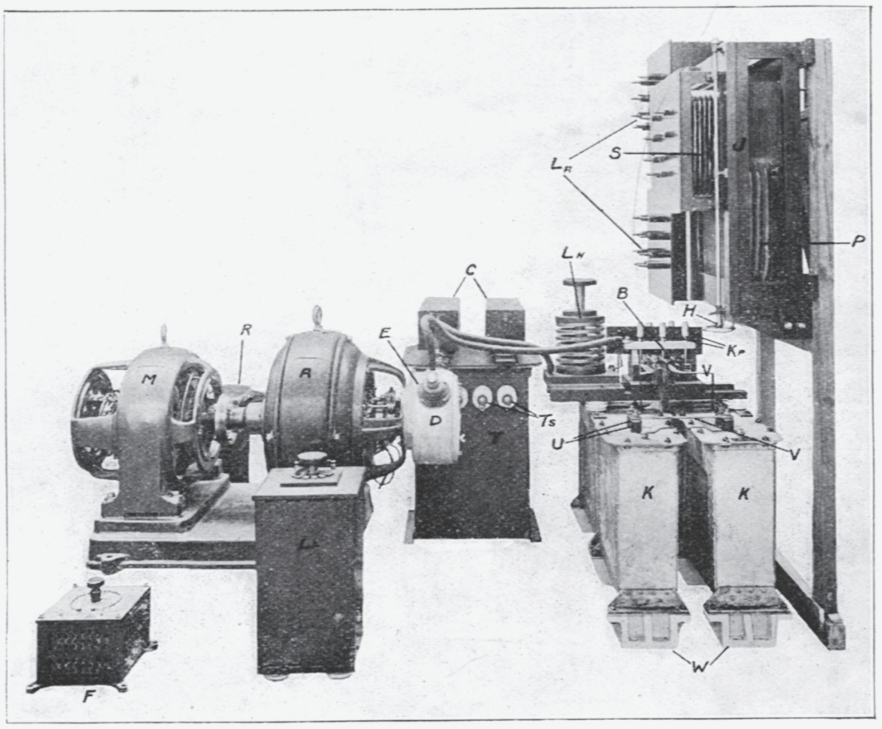


FIG. 215.—THE 5 K.W. "SPECIAL" SET.

A, Alternator.—B, Swiss Commutator.—C, Air Core Choke.—D, Disc Discharger, overhung type.—E, Disc Electrode, Terminals.—F, Field Regulator.—H, Handle of Coupling Adjusting Screw.—J, Skeleton Transmitting Jigger.—K, Tank Condenser Unit.—K_P, Condenser Plugs.—L_A, Aerial Tuning Inductance.—L_H, H.F. Primary Tuning Inductance, No. 2 Spiral.—LL, L.F, Primary Tuning Inductance.—M, Motor.—P, Jigger Primary.—R, Starter.—S, Jigger Secondary.—T, Transformer. —T_S, Transformer Secondary Terminals.—W, Porcelain Condenser Tank Supports.

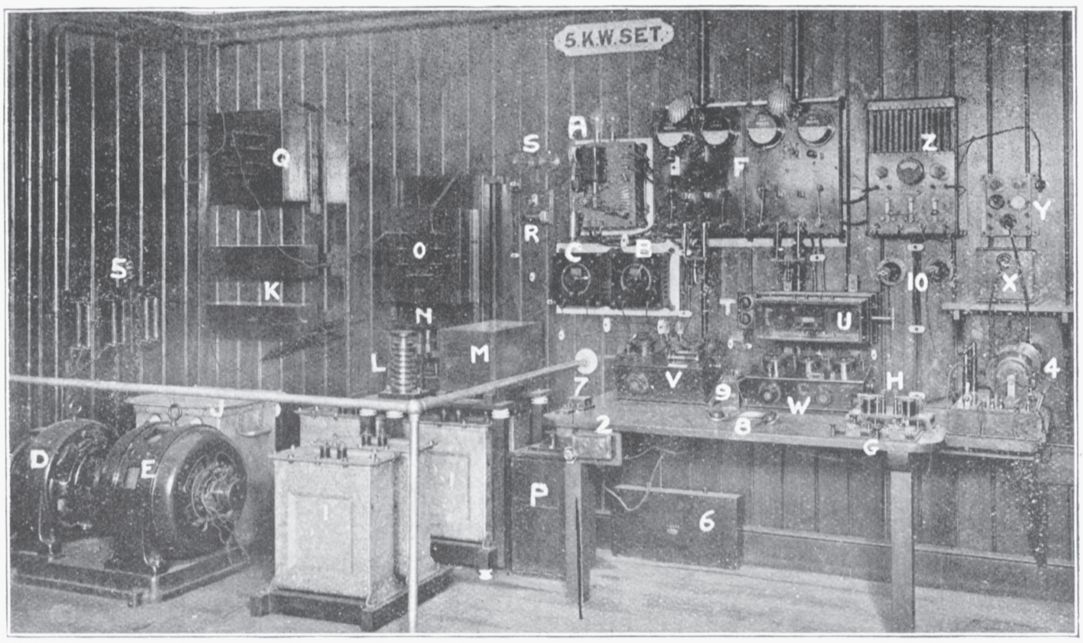


Fig. 199.—5 K.W. Plain Discharger Set, as installed at Marconi House.

A, Automatic Starter.—2, Switch for Same.—B, Motor Field Regulator.—C, Alternator Field Regulator.—D, Motor.—E, Alternator.—F, Double Panel Switchboard A.C. and D.C.—G, Manipulating Keys.—H, Double Magnetic Key.—I, Full Plate Condenser Units.—J, Transformer.—K, Air Core Choke Coils.—L, Spiral Inductance.—M, Discharger.—N, Jigger Primary.—O, Jigger Secondary.—P, Low Frequency Iron Core Inductance.—Q, Aerial Tuning Inductance.—R, Tuning Lamp.—S, Earth Arrester Spark Gaps.—T, Switch (two way).—U, Magnetic Detector.—V, Valve Detector.—W, Multiple Tuner.—X, Valve Accumulator Battery.—Y, Valve Accumulator Charging Board.—Z, Marine type Switchboard.—4, 10″ Induction Coil.—5, Guard Lamps.—6, Extra Coil Condenser.—7, Buzzer.—8, Telephones.—9, Telephone Condenser.—10, Aerial Plug Sockets.

Fig. 24-64 **5kW Spark Gap System** – A 5kW Marconi system that used a spark gap instead of the rotating disc. This is the type that is presumed to have been initially fitted to *Olympic*. This illustration also includes the standard 10in induction coil which was used for emergencies on *Titanic*.

Notes

1. Wireless reception was possible over far greater distances at night than during the day. For this reason, operators often adjusted their work schedules to send the bulk of non-urgent messages late at night.
2. The formal name of the company, as of 1900, was Marconi's Wireless and Telegraph Company Ltd; the maritime division of the company was Marconi International Marine Communication Company Ltd.
3. Marconi operators were officially known as 'Wireless Telegraphists.'
4. In the well-known photograph of *Titanic* Marconi operator Jack Phillips, his uniform cap bears the logo of the Marconi company, not the White Star Line.
5. Contrary to popular belief, *Titanic* was not the first ship to use the distress signal 'SOS'. The first recorded use of 'SOS' was from the SS *Arapahoe* adrift off Diamond Shoals, North Carolina, on the eastern coast of the United States. The *Arapahoe*'s signal was picked up by the United Wireless station at nearby Cape Hatteras.
6. The designation '7/19' refers to seven wires of nineteen strands each.
7. The term 'telephone' as used here refers to the wireless operator's headset.
8. As noted previously, *Titanic* was fitted with a 5kW installation provided with a rotary spark gap instead of the conventional fixed-type spark discharger. *Olympic* and *Titanic* were certainly among the first (if not *the* first) ocean liners to be fitted with a 5kW set with rotary spark gap.
9. 5kW sets also came with an aerial-tuning inductance which was split up into two units, one for rough adjustment having a total value of 550 mhys, and a plug socket tapping every 50 mhys, the other for fine adjustment having a total value of 50 mhys, and a plug socket tapping every 2 mhys. The large unit was subdivided into three sections which were connected by knife switches.
10. These stations were located in Cornwall, England; near Washington, D.C., in the United States; and in Paris, France, respectively.

Appendix

Ship's Principal Particulars

Builder	Harland & Wolff, Belfast
Hull (Yard) Number	401
Order to proceed with design signed	30 April, 1907
Order to proceed with construction signed	17 September, 1908
Keel laid	31 March, 1909
Launched	31 May, 1911
Sea trials	2 April, 1912
Maiden voyage	10 April, 1912
Length Overall	882ft 9in
Length between perpendiculars	850ft 0in
Breadth extreme	92ft 6in
Total height from keel to Navigating Bridge	104ft 0in
Passenger decks	8
Total decks including Tank Top	11
Watertight bulkheads	15 transverse
Sheer forward (approx)	12ft 0in
Sheer aft (approx)	4ft 0in
Camber	3in each deck for full width
Draft (forward)	34ft 6in
Draft (aft)	34ft 7in
Displacement at load draft	52,310 tons
Gross Registered Tonnage	46,328.57 tons
Net Register Tons	21,831.34
Main Engines	(2) 15,000-HP four-cylinder triple-expansion reciprocating engines (1) 16,000-HP turbine engine
Combined total horsepower	46,000 (designed)/59,000+ (maximum, based on *Olympic*)
Boilers	24 double-ended, 5 single-ended
Working pressure	215 PSIG
Total number of furnaces	159
Total grate area	3,466sq.ft
Total heating surface of furnaces	144,142sq.ft
Estimated coal consumption at 21 knots	1.25 lbs/HP/hr (based on *Olympic*)
Bunker Capacity (maximum)	6,611 tons
Main Electrical generating plant	(4) 400kW dynamos, total output 16,000 amperes @ 100VDC
Emergency Electrical generating plant	(2) 30kW dynamos, total output 600 amperes @ 100VDC

Bibliography

DOCUMENTS

Harland & Wolff, Belfast, Olympic *Specification Notebook – Drawing Office Copy* (1911).

Harland & Wolff, Belfast, Archives: *Particulars of Ships, entries for steamships Nos 400 and 401* (1908–1912).

Harland & Wolff, Belfast, *Main construction drawings for steamships No.400, 401 and 433* (1908–1914).

Knight, Frank & Rutley, Auctioneers, *Catalogue of the Contents and Equipment of the* Olympic (Printed in London by H. Davy, 1935).

National Archives of the UK: *Admiralty and Board of Trade: Surveys and Inspections:* 'Olympic' (O.N. 131346: BT 15/504).

National Archives of the UK: Treasury Solicitor and H.M. Procurator General's Department: Report of Proceedings: *Collision between HMS* Hawke *and SS* Olympic *off the Isle of Wight: report of proceedings* (TS 136/175, 136/176, 136/183, 116/1163).

National Archives of the UK: Admiralty and Board of Trade: *Loss of S.S.* Titanic. *Report of Court of Inquiry* (BT 13/50).

National Archives of the UK: Admiralty and Board of Trade: Registrar General of Shipping and Seamen and Predecessor: *Agreements and Crew Lists,* Titanic (Series III, Nos 100/259 and 100/260).

National Archives of the UK: Admiralty and Board of Trade: Board of Trade and Ministry of Transport and successors: Marine, Harbours and Wrecks Files: *Carriage of flags by British merchant ships* (MT 9/358).

National Museums of the UK: Liverpool: Maritime Archives and Library: Cunard Line Archives: *Draft report by Leonard Peskett, Naval Architect, Cunard Line, re passage on White Star Line ship* Olympic (August 19–26, 1911: B/CUN/3/8/1).

US National Archives: New York: Record Group 21: Records of District Courts of the United States: New York, Southern District: Limitation of Liability Hearings for the loss of the *Titanic* (1912).

US National Archives: New York: *Immigration and shipping records for arrivals in the Port of New York* (1911).

US National Archives: New York: *Records of the United States Senate Inquiry into the loss of the* Titanic (1912).

PERIODICALS

'The Electrical Equipment of the S.S. "*Olympic*" and "*Titanic*" (part I)', *The Electrician*, vol. 67, July 28, 1911: 615–619.

'The Electrical Equipment of the S.S. "*Olympic*" and "*Titanic*" (part II)', *The Electrician*, vol. 67, August 4, 1911: 658–662.

'Harland and Wolff's Works at Belfast', *The Engineer*, supplement June 18, 1909.

'Stern Frames and Brackets of the New White Star Liners', *The Engineer*, Dec. 17, 1909: 632–633.

'The White Star Line', *The Engineer*, supplement June 24, 1910.

'Electric Lifts on the *Olympic* and *Titanic*', *The Engineer*, June 24, 1910: 64.

'The White Star Liners *Olympic* and *Titanic*', *The Engineer*, Aug. 27, 1910: 226.

'Engineering Exhibition at Olympia', *The Engineer*, Sept. 16, 1910: 297–298.

'The Launch of the *Olympic*', *The Engineer*, Oct. 21, 1910: 433–435.

'Helical Gears for Steering Apparatus of the New White Star Liners', *The Engineer*, Oct. 21, 1910.

'The White Star Liner *Britannic*', *The Engineer*, Feb. 27, 1914: 240–241.

'R.M.S. *Britannic*', *The Engineer*, March 6, 1914: 257–259.

'Kilroy's Stoking-Indicators', *Engineering*, vol. 76, October 2, 1903: 454–456.

'The World's Naval and Merchant Shipbuilding', *Engineering*, vol. 89, January 21, 1910: 86–87.

‘The Welin Quadrant Davit for Double-Banked Lifeboats’, *Engineering*, vol. 90, July 1, 1910: 14-15.

‘The White Star Liner “*Olympic*” (part I)’, *Engineering*, vol. 90, October 21, 1910: 564-572.

‘The White Star Liner “*Olympic*” (part II)’, *Engineering*, vol. 90, November 18, 1910: 620-621, 693-695.

‘The White Star Liners “*Olympic*” and “*Titanic*”’, *Engineering*, vol. 91, May 26, 1911.

‘Harland and Wolff’s Works at Belfast’, *Engineering*, vol. 94, July 5, 1912: 3-50.

‘The White Star Liner “*Olympic*”’, *Engineering*, vol. 95, March 28, 1913: 426.

‘The White Star Liner “*Britannic*”’, *Engineering*, vol. 97, February 27, 1914: 273-283.

Bruns, James H., ‘*Titanic*’s Mail’, *En route* magazine, vol. 1, Issue 1, January–March 1992. Abstract on website of National Postal Museum: http://www.postalmuseum.si.edu/resources/6a2a_titanic.html

‘Illumination of the World’s Largest Steamship’, *The Illuminating Engineer*, July 1911.

Lome, Herbert M., ‘The Sanitation of a Modern Ocean Liner (Part I)’, *Modern Sanitation*, vol. 8, No.12, Dec 1911: 445-451.

Lome, Herbert M., ‘The Sanitation of a Modern Ocean Liner (Part II)’, *Modern Sanitation*, vol. 9, No.1, Jan. 1912: 12-16.

‘The White Star Liners “*Olympic*” and “*Titanic*”’, *The Shipbuilder*, souvenir issue No.21, summer 1911.

‘Aquitania’, *The Shipbuilder*, souvenir issue No.46, spring 1914.

Kamuda, Karen, ‘The Story of the White Star House Flag’, *The* Titanic *Commutator*, vol. 23, No.146, 1999: 92-94.

Payne, B. A., ‘Dinner Aboard the *Titanic*’, *The* Titanic *Commutator*, vol. 19, No.3, 1995: 34-45.

‘Passenger Lifts on Ocean Steamers’, *The Railway And Travel Monthly*, December 1912.

INTERNET SOURCES

‘Posted Aboard the RMS. *Titanic*.’ Smithsonian: National Postal Museum: Exhibits: http://www.postalmuseum.si.edu/titanic

‘Harbor Boat Mail Service.’ Smithsonian: National Postal Museum: Exhibits: http://www.postalmuseum.si.edu/exhibits/2b1c5_mailboat.html

‘*Titanic* Navigation’ by Dave Gittins: http://users.senet.com.au/~gittins/navigation.html

BOOKS

Audels New Marine Engineers Guide (New York: Theo. Audel, 1918).

Baker, E., *Introduction to Steel Shipbuilding* (London: McGraw-Hill, 1943).

Baker, G. S., *Ship Form, Resistance and Screw Propulsion* (New York: D. Van Nostrand, 1915).

Blocksidge, E. W., *Ship’s Boats*. (London: Longmans, Green, 1920).

Brinnin, John M., *The Sway of the Grand Saloon*. (New York: Delacorte Press, 1971).

Brown’s Signalling (Glasgow: James Brown, 1914).

Cameron, S., Titanic*: Belfast’s Own* (Dublin: Wolfhound Press, 1998).

Chirnside, Mark, *The* Olympic*-Class Ships* (Stroud, Gloucestershire: Tempus, 2004).

Clark, Claude, *Primer of Ship Blueprint Reading* (New York: Cornell Maritime Press, 1942).

Clifford, C. R., *Period Furnishings – An Encyclopedia of Historic Decorations and Furnishings* (New York, Clifford & Lawton, 1927).

Cook, C. W., *Steel Shipbuilder’s Handbook* (New York and London: Longmans, Green, 1918).

Duckworth, S. G., *Ship Joinery* (London: George Rutledge & Sons, 1923).

Dunn, Laurence, *Fifty Famous Liners, Belfast Built* (London: Adlard Coles, 1964).

Fletcher, R. A., *Travelling Palaces* (London: Sir Isaac Pitman & Sons, 1913).

Forsyth, Alastair; Hyslop, Donald and Jemima, Sheila, *Titanic Voices – Memories from the Fateful Voyage* (New York: Sutton Publishing, 1997).

Gracie, Col. Archibald, *The Truth About the* Titanic (New York: Mitchell Kennerly, 1913).

Griffiths, Dr Denis, *Power of the Great Liners* (London: Patrick Stephens, 1990).

Hawkshead, J. C., *Handbook of Technical Instruction for Wireless Telegraphists* (London: Marconi Press Agency, 1913).

Hayes, Sir Bertram, *Hull Down* (New York: MacMillan, 1925).

Heed, H. L., *Ship Structure and Blueprint Reading* (New York: Cornell Maritime Press, 1942).

Holmes, A., Campbell, *Practical Shipbuilding, vol. I and II* (London: Longmans, Green, first ed. 1904, second ed. 1908 and third ed. 1918).

Haas, C. A., and Eaton, J. P., Titanic *– Triumph and Tragedy* (Somerset: Patrick Stephens, 1986).

Haddon, I. J., and Haddon, H. A., *Practical Treatise for Boilermakers* (Cardiff: Published by the authors; printed by Western Mail, 1913).

Johnson, T. M., *Ship Wiring and Fitting* (London: Constable, 1911).

Lightoller, C. H., Titanic *and Other Ships* (London: Nicholson and Watson, 1935).

Low, D. A., *Heat Engines* (London: Longmans, Green, 1920).

Major, A., *Maritime Antiques – An Illustrated Dictionary* (New York: A. S. Barnes, 1981).

MacGibbon, W. C., *B.O.T. Orals and Marine Engineering Knowledge, Steam and Motor* (Glasgow: James Munro, 1938).

Malcolm, John, *The Merchant Shipping and Relative Acts Classified for Ready Reference* (London: William Hodges, 1911).

Marine Auxiliaries (New York: Griscom-Russel, 1918).

Maxtone-Graham, John, *Ocean Liners of the Past:* Olympic *and* Titanic (New York: Amereon, 1995).

McCaughan, Michael, *Birth of the* 'Titanic' (Belfast: Blackstaff Press, 1998).

Moore, Hubert S., *Rules of the Road at Sea* (London: J. D. Potter, 1900).

Moss, M. and Hume, J. R. *Shipbuilders to the World* (Belfast: Blackstaff Press, 1986).

Nicol, G., *Ship Construction and Calculations* (Glasgow: James Brown & Son, 1909).

Newstead, Ralph, *Audels Shipfitter's Handy Book* (New York: Theo. Audel, 1940).

Osbourne, Alan, *Modern Marine Engineer's Manual* (New York: Cornell Maritime Press, 1941).

Parsons, Sir Charles, *The Steam Turbine* (Cambridge University Press, 1911).

Perrin, W. G., *British Flag* (Cambridge: University Press, 1922).

Pollard, Captain W. F., *Daily Steamship Duties, Points to Remember in Every-Day Life on a Steamer* (Glasgow: James Brown & Son, 1924).

Pounder, Cuthbert Coulson, *Machinery and Pipe Arrangement on Shipboard* (Manchester: Emmott, 1922).

Pounder, Cuthbert Coulson, *The Design of Flat Plates* (Gateshead-on-Tyne: Association of Engineering and Shipbuilding Draughtsmen, 1920).

Riesenberg, F., *Standard Seamanship for the Merchant Service* (New York: D. Van Nostrand, 1922).

Seaton, A., *The Screw Propeller and Other Competing Instruments for Marine Propulsion* (London: Chas. Griffin, 1909).

Sennett, Richard, and Oram, Vice Admiral Sir Henry J., *The Marine Steam Engine* (London: Longmans, Green, 1911).

Shipbuilding Cyclopedia (New York: Simmons-Boardman, 1920).

Simpson, G., *The Naval Constructor* (New York and London: D. Van Nostrand, 1904).

Smith, W. J., *Practical Compass Adjustment* (Seattle, Washington: Denny-Coryell, 1894).

Sothern, J. W. M., *The Marine Steam Turbine* (Glasgow: James Munro, 1919).

Sothern, J. W. M., *Verbal Notes and Sketches for Marine Engineers* (Glasgow: James Munro, 7th ed. 1911 and 15th ed. 1943).

Sterling, Frank Ward, *Marine Engineer's Handbook*. (New York and London: McGraw-Hill, 1920).

Swanson, W. E., *Modern Shipfitter's Handbook* (New York: Cornell Maritime Press, 1941).

Talbot, Frederick A., *Steamship Conquest of the World* (London: William Heinemann, 1912).

Thearle, S. J. P., *The Modern Practice of Shipbuilding in Iron and Steel* (London: Collins Press, 1910).

Trask, Edgar P. and Comstock, John P., *Ship Drafting* (Scranton, Pa: International Textbook, 1938).

Tulin, Adam F., *Practical Shell Developing for Steel Shipbuilders* (New York: Simmons-Boardman, 1938).

Walker, S., *Cold Storage, Heating and Ventilating Onboard Ship* (New York: D. Van Nostrand, 1911).

Walton, T., *Steel Ships: Their Construction and Maintenance* (London: Charles Griffin, 1908).

Walton, T., *Steel Ships: Know Your Own Ship* (London: Charles Griffin, 1927).

Warren, M., *Distinguished Liners from* The Shipbuilder *1906-1914 volume 1* (New York: Blue Riband Publications, 1995).

Warren, M., *Distinguished Liners from* The Shipbuilder *1907-1914 volume 2* (New York: Blue Riband Publications, 1997).

Watson, Thomas H., *Naval Architecture: a Manual on Laying-off Iron, Steel, and Composite Vessels* (Newcastle-Upon-Tyne: Andrew Reid, 1912).

Welch, George S., *The Ship Painter's Handbook* (Glasgow: Brown, Son & Ferguson, 1936).

Wilson-Barker, D., *A Manual of Elementary Seamanship* (London: Chas. Griffin, 1913).

Wilson, V. S. Fellowes, *The Largest Ships in the World*. (London: Crosby, Lockwood & Son, 1926).

Wright, L., *Clean and Decent: The Fascinating History of the Bathroom & the Water Closet* (New York: Viking Press, 1960).

Website References

Titanic Research and Modeling Association (TRMA)

The Titanic Research and Modeling Association is the best source for progressive technical research of the *Olympic*-class ships. The TRMA website below has a forum where topics in this book can be discussed with the authors, and the Association also offers a professional consultation and advisory service upon request.

'The TRMA – Changing the Way the World Looks at Titanic.'

www.titanic-model.com

* * *

A full set of General Arrangement plans for *Titanic*, from which the General Arrangement plan details in this book were taken, can be obtained from the Titanic Historical Society:

www.titanichistoricalsociety.org

* * *

CAD plans for *Titanic*, with elevation and plan views of the exterior of the ship in various scales for modeling, can be obtained from the following sources:

Robert Hahn: www.titanic-plan.com

Bob Read: www.titanic-cad-plans.com

* * *

TITANIC – The Ship Magnificent

Information about the book, chapter excerpts and author profiles can be found at:

www.titanic-theshipmagnificent.com

Glossary of
Ship, Shipbuilding and Shipfitting Terms

Note: The majority of these terms have been defined in the present tense, as if the reader was referencing these definitions at the time of Titanic*'s construction.*

Abaft Towards the stern; aft, relative to.

Abeam At right angles to the vessel's longitudinal axis and in her plane of flotation.

Aboard On a ship or boat.

Aboveboard Above deck, as distinguished from in the hold or below decks.

Abreast Even with; opposite. See also 'Abeam'.

Aft In the direction of or toward the stern.

After Collision Bulkhead See 'Bulkhead, After Peak'.

After Deck See 'Deck, After'.

After Peak A compartment immediately forward of the stern post. Generally situated entirely below the load waterline.

After Peak Bulkhead See 'Bulkhead, After Peak'.

After Perpendicular A line perpendicular to the base line, intersecting the after edge of the stern post at the designed waterline.

Aground The situation of a ship in which its bottom touches or rests on the ground; stranded.

Ahead Forward; in front of.

Air Ejector A steam ejector connected to the condenser dry suction for the purpose of discharging the air and vapor into the atmosphere. A condensate pump handles the condensed steam.

Air Pipes Pipes leading from tanks to the open air as vents or to provide a supply or escape of air when pumping out or filling the tanks.

Air Trunk or Conduit The passage forming the main air supply to a fan or exhaust from a fan.

Air and Circulating Pump See 'Pump, Air and Circulating, Auxiliary'.

Aloft Up on the mast or in the rigging; above the decks.

Alley, Shaft See 'Tunnel, Shaft'.

Alternating Current (AC) An electric current in which the instantaneous values of current at any point in the circuit vary from zero to a positive maximum value, back to zero, then to a negative maximum value and back to zero again. When plotted it consists of half waves of equal area in successive opposite direction from the zero line.

Amidships In the vicinity of the middle portion of a vessel as distinguished from her ends. The term is used to convey the idea of general locality rather than a specific location on the ship.

Ammeter An instrument for measuring the electric current flowing in a circuit. The scale of the meter is calibrated to read in amperes.

Ampere The practical unit of electric current. It represents that value of current which will cause the electrolytic deposition of silver at the rate of 0.001118 grams per second.

Anchor A heavy iron or cast steel implement attached to a vessel by a rope or chain cable. When the anchor is properly deployed it takes hold of the ground and prevents the vessel from drifting further than the length of anchor cable paid out. The anchor is 'let go' when it is permitted to drop to the bottom; 'apeak' when the cable is taut and vertical or nearly vertical beneath the bow; 'atrip' when the anchor breaks free of the bottom; 'aweigh' when it is raised off the bottom, and 'awash' when it breaks the surface of the water.

Anchors, Bower The principal anchors carried by a vessel. They are so named because they are carried on the bows. In earlier times they were of different weights, the larger being known as the *best* bower and the smaller as the *small* bower. These anchors are now usually the same size.

Anchor-Handling Gear The windlass and gear installed aboard ship for letting go, taking in and handling the anchor.

Anchor, Kedge A light anchor used for warping or kedging.

Anchor, Mooring An anchor used to hold a mooring buoy or channel marker in place, or to which a ship is made fast instead of dropping her own anchor. A mooring anchor is designed to be permanently deployed. Large anchors of the mushroom type are typically used for mooring.

Anchor, Stockless An anchor which, by virtue of being designed without a stock, permits the shank of the anchor to be drawn up and housed within the anchor hawse of a vessel.

Anchor, Stream An anchor used for anchoring in a narrow roadway or channel to prevent the stern swinging with the tide. The weight of this anchor is typically equal to about one-fourth that of the bower anchor. Occasionally termed a 'stern anchor'.

Anchorage (1) A suitable place for a ship to lie at anchor. (2) Harbor dues for anchoring in a port.

Angle An abbreviated term for an angle iron or angle bar.

Angle Bar A rolled shape, generally of mild steel, having a cross-section shaped like the legs of a right angle. In ship work it is used for frames, bulkhead stiffeners, attachment of one plate or shape to another, etc. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Anneal To soften metal by heating and slowly cooling. In annealing cast iron the carbon is burned out near the surface, leaving the outer surface tough and strong while the interior remains hard.

Aperture The space provided between the propeller and stern post for the propeller.

Appliqué *(French)* From the word *appliquer*, meaning '*to apply*', meaning a fitting or decorative feature applied to a surface. In the case of *Titanic*, this word is most frequently used to refer to an electric light sconce mounted to a wall.

Apron In small boat construction, a reinforcing timber bolted to the after side of the stem or stern post and which provides the surface for securing the hood-ends of the planking.

Arch Piece of stern frame The curved portion of the frame over the screw aperture, joining the propeller post and stern post.

Arc Lamp See 'Lamp, Arc'.

Ash Ejector An apparatus for utilizing the discharge water from a pump to convey ashes from the boiler room up and out through the vessel's side above the waterline. It consists of a metal pipe or chute leading overboard above the waterline. At the lower end in the boiler room a hopper is located, and into this the discharge from the pump is led. With the hopper closed and discharge valve opened the stream from the pump will pass with high velocity. The cover may then be removed and ashes dumped into the hopper from which they will be rapidly conveyed overboard by the water.

Ash Expeller An apparatus for the discharge of ashes from the boiler room below the water level. In this apparatus the ashes are placed in the hopper, from which they pass through a quick acting valve to an intermediate chamber. An air blast or hydraulic jet expels them from this chamber.

Ash Hoist Gear for the removal of ashes from the boiler room. It consists of a bucket or reinforced canvas bag, usually traveling in guides, a winch for hoisting same to the Weather Deck or to an ash room on an Upper Deck, and sometimes a trolley track to the ship's side.

Astern (1) Signifying position, in the rear of or abaft the stern. (2) The opposite of going ahead; backwards.

Athwart, Athwartship In a transverse direction; from side to side at right angles to the fore-and-aft centerline of a vessel.

Auxiliary Feed Pump See 'Pump, Auxiliary Feed'.

Auxiliary Foundations See 'Foundation, Auxiliary'.

Auxiliary Machinery As the name implies, this includes all machinery except the boilers and engines constituting the propelling machinery proper, and the deck machinery. Under this heading are included such items as Air Pumps, Ash Ejectors, Blowers, Bilge Pumps, Circulating Pumps, Condensers, Distillers, Evaporators, Fans, Feed Heaters, Feed Pumps, Filters, Injectors, Lubricating Oil Pumps, Oil Pumps, Sanitary Pumps, Transfer Pumps, Water Pumps, etc.

Avast (1) A command to cease pulling on a rope. (2) To stop; cease.

Awning A canvas canopy suspended over a vessel's decks, bridges, etc., for protection against rain and sun.

Azimuth The azimuth of a star is the distance of that body in angular degrees from north or south point of the meridian, or the angular distance measured along the horizon between the meridian of a place and the vertical circle passing through the center of a celestial object and the zenith.

Azimuth Circle A graded ring attached to a compass. It is used in taking the bearings of the sun, stars and terrestrial objects.

Azimuth Compass (Vertical Compass) A form of compass divided into degrees, with vertical sights used for taking the azimuth of a star.

Backbone The keel of a ship. Sometimes refers to the center vertical keelson.

Backstays A rope, whether hemp or wire, that supports a mast and runs predominantly aft from the mast.

Ballast Any weight carried solely for the purpose of making the vessel more seaworthy. Ballast may be either portable or fixed, depending upon the condition of the ship. Ballast is divided into two basic categories as follows: (1) permanent ballast, in the form of sand, concrete, scrap or pig iron which is usually fitted to overcome an inherent defect in stability or trim due to faulty design or changed character of service; and (2) portable ballast, usually in the form of water pumped into or out of bottom, peak or wing ballast tanks, which is utilized to overcome a temporary defect in stability or trim due to faulty loading, damage, etc.

Ballast, Water Seawater confined to double bottom tanks, peak tanks or other designated compartments for use in obtaining satisfactory draft, trim or stability.

Baluster A small upright pillar or column supporting the hand rail around a staircase.

Bar Iron Rolled bars having various forms of curvature.

Barometer An instrument for measuring atmospheric pressure or weight to determine likely weather changes.

Barometer, Aneroid; and Barometer, Barograph Instruments to measure and record on paper the variations of atmospheric pressure during a period of time.

Batten (1) A thin strip of wood, usually tapered, used in laying down lines in a mold loft. (2) A strip of wood or steel used in securing tarpaulins in place (see 'Battens, Hatch'). (3) To secure by means of battens, as to 'batten down a hatch'. Also see Battens, Cargo.

Battening Bars See 'Battens, Hatch'.

Batten Down To make the hatches watertight by means of tarpaulins firmly secured to the hatch coamings with battens, wedges, etc. Also see 'Battens, Hatch'.

Battens, Cargo The planks that are fitted to the inside of the frames in a hold to keep the cargo away from the shell plating.

Battens, Hatch The flat bars used to fasten and make tight the edges of the tarpaulins that are placed over hatches. The batten and edge of the tarpaulin are wedged tightly in closely spaced cleats.

Beam (1) The extreme width of a ship. (2) A transverse, horizontal member, either permanent, portable or temporary, which supports a deck, flat or hatch cover, or is introduced to structurally tie to one another the frames on opposite sides of the ship.

Beam Angle Bar An angle bar used in the construction of a deck beam or an angle bar composing a deck beam.

Beam, Cant Any of the beams not square to the longitudinal centerline which support the deck plating in the overhanging part of the stern of the vessel. Typically, they radiate in a fan shape from the transom beam to the cant frames.

Beams, Hatch The portable beams fitted to the coamings for the purpose of supporting the hatch covers. The ends of these beams receive hard usage in shipping and unshipping and should be reinforced at these points by doubling strips.

Beam, Hold Any one of a tier of athwartship beams spanning the hold from frame to frame, and upon which no deck is fitted.

Beam, Intermediate A beam that is fitted in between, and running parallel to, the regularly spaced deck beams.

Beam Knees (1) A block of wood having a natural angular shape or a block cut to a bracket shape and used for connecting the deck beams to the frames in a wooden vessel. (2) The ends of steel deck beams that are split, having one portion turned down and a piece of plate fitted between the split portion, forming a bracket end. Also see 'Knee'.

Beam, Main The deck beam fitted at the point of maximum breadth of the vessel.

Beam, Molded The width over the widest portion of the ship measured to the outside of the frame angles or channels but inside the plating.

Beam, Molded, Extreme The greatest width outside the plating or any part of the hull proper. Sometimes, but not always, taken over guards or fenders.

Beams, Deck Any of the main beams upon which the plating or planking of a deck is supported. These beams usually run athwartship and are fastened to the frames. In the way of hatch openings they run from the side to the opening and are bracketed or clipped to the casing or coaming as the case may be. In fore-and-aft framing the beams run longitudinally and are bracketed to the bulkheads and also supported by heavy transverse web or belt beams.

Beam, Transom A strong deck beam situated in the after end of a vessel directly over the stern post, and connected at each end to the transom frame. The cant beams which support the deck plating in the overhang of the stern radiate from it.

Bearding In small boat construction, the curving of the deadwood to suit the form of the boat.

Becket The extension of the cheek straps of a block, together with the bolt and thimble or eye bolt to which is secured the standing part of the fall.

Bed Plate A structure consisting of a series of transverse girders connecting fore-and-aft members or girders. It is usually made of cast iron or steel, the girders having box or L-shaped sections. It may be either cast in one piece or built up of several castings bolted together. The bed plate is fitted for the support of the feet of the engine columns, as well as to provide for the support of the crankshaft bearings. It also assists in the distribution of the engine weight and stresses to the ship structure to which it is attached by holding down bolts.

Beetle A heavy, long-handled wood mallet with metal hoops, sometimes called a reaming beetle or hawing beetle, used by caulkers for striking a reaming or horsing iron.

Before Toward the stem or in front of the vessel.

Belay To secure a rope or line about a cleat or belaying pin by winding it back and forth in the manner of a 'figure-of-8'.

Belaying Pin A small pin of iron or tough wood, consisting of a head, shoulder and shank. The pin, being securely fitted in a rail, is used for belaying the hauling parts of light running gear, signal halyards, etc.

Bending Moment Any beam, girder or structure subject to bending is acted upon by a 'bending moment'. The bending moment at any point in the structure is the sum of the products of the force acting to produce bending and the perpendicular distances from the lines of action of the forces to the point under consideration.

Bending Slab or Block A cast-iron slab usually about 5ft square, perforated with holes 2in square, arranged in a manner similar to a checker board. The slab is generally about 2in thick except around the edges where it is about 8in deep. The floor in front of the furnace in the Plate and Angle Shop is made up of a number of these slabs raised to the level of the furnace door. Such work as furnacing plates and bending and beveling is done on these slabs, the holes being used for setting pins around which to bend frames and providing a means for dogging down the work and any forms used.

Berth (1) A bed or a place to sleep. Berths, as a rule, are permanently built into the structure of the staterooms or compartments. They are constructed singly and also in tiers of two or three, one above the other. Tiers of berths constructed of pipe are commonly installed in crew spaces. (2) A stateroom or cabin. (3) A position; for example, the berth of 2nd Mate. (4) The place where a ship is docked or tied up.

Between Decks See ''Tween Decks'.

Bevel Gear A gear designed to transmit power from one shaft to another with which it makes a definite angle. When the shafts are at right angles to each other, the gears are called miters.

BHP See 'Horsepower, Brake'.

Bibb The bent outlet of a cock. See 'Cock'.

Bight (of a rope) A loop or bend in a rope, though, strictly considered, any part between the two ends may be termed the bight.

Bilge (1) The rounded portion of a vessel's shell which connects the bottom with the sides. (2) To open a vessel's lower body to the sea, as through collision or grounding.

Bilge and Ballast System A system of piping generally located in the hold of a vessel and connected to pumps. This system is used for pumping overboard accumulations of water in holds and compartments, and also for filling and emptying ballast and peak tanks.

Bilge Water Drainage water which accumulates either in the bottom or bilge.

Binding Strake In small boat construction, the first plank applied to the timbers near the top. So called because it tends to bind the hull together.

Binnacle A stand or case for housing a compass so that it may be conveniently consulted. Binnacles differ in shape and size, according to where used and the size of compass to be accommodated. A binnacle for a ship's navigating compass consists essentially of a pedestal at whose upper end is a bowl-shaped receptacle having a sliding hood-like cover. This receptacle accommodates the gimbals supporting the compass. Compensating binnacles are provided with brackets or arms on either side, starboard and port, for supporting and securing the iron cylinders or spheres used to counteract the quadrantial deviation due to the influence of the iron and steel of the ship on the compass. This type of binnacle is usually placed immediately ahead of the steering wheel, having its vertical axis in the vertical plane of the fore-and-aft centerline of the vessel.

Bitts Short metal or wood columns extending up from a base plate attached to a deck or bulwark rail; timbers protruding through and a short distance above a deck; or columns fitted to a windlass for the purpose of securing and belaying ropes, hawsers, cables, etc. Also called bollards, although this term more properly refers to similar structures on a dock or wharf.

Bitts, Mooring The bitts to which the mooring lines are attached.

Bitts, Towing The bitts fitted on the deck of a vessel for the purpose of belaying or fastening the towing hawsers.

Bitumastic A black tar-like composition largely of bitumen or asphalt and containing such other ingredients as rosin, Portland cement, slaked lime, petroleum etc. It is sold under various trade names in the form of a solution, an enamel, and a cement, the exact composition being kept more or less a secret by the manufacturers. All three forms adhere well to steel when properly applied and are practically impervious to water. The solution is applied cold with a brush and is used as a priming coat for either the enamel or cement. The enamel is applied hot, after the solution is nearly dry or set, by being poured, where practicable, or otherwise spread over the surface, forming a fairly elastic surface after hardening and cooling. The cement is also applied hot, but being more difficult to apply than the enamel, is used generally only on horizontal surfaces. The solution and enamel or cement is used as a protective coating in ballast and trimming tanks, chain lockers, reserve feed and fresh water tanks, coal bunkers, engine and boiler foundations, shaft alleys and below floor plates in vessels and as a damp-proof coating on the walls of cold storage spaces.

Black Gang The crewmen responsible for working the boiler rooms and the adjacent coal bunkers.

Block A device used in applying power to move heavy weights by means of tension in a cable. It consists of a frame made of wood or metal containing one or more pulleys or sheaves, set side by side and turning on the same axis. If more than one sheave is fitted, the sheaves are separated by divisions of the same outline as the sides or cheeks of the block. In referring to blocks the words single, double or triple are prefixed to indicate the number of sheaves they carry in their frames.

Block, Snatch A single block with a hook having one end of the frame arranged so that it can be hinged up to allow the bight of a rope to be placed on the one end of the rope through the swallow. Snatch blocks are used to lead ropes around obstructions which prevent straight leads to a winch or capstan.

Blocks, Gin Single blocks with a metal frame having a sheave of large diameter for ease in overhauling and used where the operation of hoisting by a single part is to be performed many times in succession as in hoisting cargo. Sometimes called 'gins'.

Blue Peter A rectangular blue flag with a large white rectangle in its center, hoisted as a signal that the ship is about to sail.

Board To come onto a vessel. Usually refers to passengers, but also used to refer to large seas that wash over the ship's decks, as in 'boarding seas'.

Board, by the To go over the side of the ship and into the water.

Board, Bevel A wooden board upon which is drawn the bevels applying to some part of the ship's structure such as the frames, and given to the workmen in the yard for ready reference where a paper plan or sketch would not stand rough usage.

Boat Hook A metal fitting in the form of one or more hooks and a prong, attached to the end of a pole. They are used for catching, holding and steadying small boats.

Boat Stowage The provisions made aboard a ship for stowing and launching life boats.

Boat Tanks See 'Buoyancy Tanks'.

Boatswain (Bosun) The petty officer who has immediate charge of the deck force, deck gear, boats, rigging, cordage, etc.

Boatswain's Chair (Bosun's Chair) A piece of plank forming a seat, hung in two straps or lines, by which a man may be hoisted aloft or lowered over the ship's side.

Body, After That portion of a ship's body abaft the midship section.

Body, Fore That portion of a ship's body ahead of the midship section.

Body Plan A drawing view consisting of a pair of half transverse elevations or end views of a ship, both having a common vertical centerline, so that the right-hand side represents the ship as seen from ahead, and the left-hand side as seen from astern. On the body plan appear the forms of the various cross-sections or 'stations', the curvature of the rail and deck lines at the side, and the projections as straight lines of the waterlines, bow and buttock lines, and the diagonal lines.

Boiler Any vessel, container or receptacle that is capable of generating steam by the internal or external application of heat. There are two general classes of boilers, fire-tube and water-tube.

Boiler Bracket A bracket connecting the boiler to the ship's structure.

Boiler Combustion Chamber A chamber or space adjacent to the furnace in a boiler designed for the purpose of completing the combustion of the gases from the fuel.

Boiler Compounds Substances, generally having a soda or tannic content that are injected into the boiler with the feed water or through a soda cock. These compounds should be used to prevent scaling, rather than to break it up after it has already occurred. Care should be taken to suit the compound to the water used rather than to use the compound as a cure-all.

Boiler Corrosion Destruction of the steel parts due to the oxidizing properties of the feed water. It may result from galvanic action, the presence of air or the acidity of the water.

Boiler Feed Water The water supplied to steam boilers. The feed water should be as free from the carbonates and sulphates of lime and magnesia as possible. Hard or salt water should never be used except in an emergency. Due to the fact that water loses its solubility at high temperatures these substances are deposited in the form of scale upon the heating surfaces.

Boiler Feed-Water Heater A vessel or container used for heating the feed water before it is injected or pumped into the boiler. The feed water may be heated by passing it through tubes around which the exhaust steam, or in some cases live steam, circulates, by allowing the water to circulate around tubes through which exhaust or live steam passes, or by causing the feed water to fall in a shower of droplets through a cloud of exhaust or live steam. Other types which are frequently called 'economizers' utilize the heat from the waste flue gases. The advantages of a feed water heater are that it utilizes heat that would otherwise be wasted, and increases the steam capacity by shortening the time necessary to bring the water up to steaming temperature. Feed-water heaters also prevent strains in the boiler due to the introduction of cold water, they retain a large portion of the scale that would otherwise be deposited in the boiler, and they remove a large part of the dissolved air contained in feed water, the primary cause of pitting and corrosion within boilers.

Boiler Feed-Water Make-Up Water supplied to steam boilers to make up for losses occurring from steam leaks in pipe joints and stuffing boxes and from other causes.

Boiler, Fire-Tube A boiler in which the hot gases from the furnaces and combustion chambers are led to the uptakes through tubes around which water circulates. Sometimes referred to as a 'Smoke-Tube Boiler'. Fire-tube boilers have the following advantages over water-tube boilers: less damage is done if it should become necessary to use salt water; not as much attention need be given to the regulation of the supply of feed water; less trouble is experienced with the tubular elements; less sensitive to mishandling through lack of maintenance or by Firemen who are below the average in experience or intelligence; the initial cost of construction is far less. The most common type of fire-tube boiler fitted for marine applications is the 'Scotch Boiler'. See Boiler, Scotch.

Boiler Firing The process of supplying fuel to the furnace(s) of a boiler and maintaining the fire in order to achieve optimum combustion. No general rule for firing can be given, as the desirable thickness of the fire and methods used depend on the quality of the fuel, draft and numerous other conditions. With bituminous coal there are two common methods, called spreading and coking. In the spreading method the coal is thrown evenly in a thin layer over one furnace at a time. This method requires frequent firing. In the coking method the coal is thrown in the forward end of the furnace and allowed to coke, whereby the volatile parts of the coal, including water, coal-gas and coal-tar, are driven off so that the fixed carbon and residual ash are fused together; afterwards, the coal is then spread out over the entire furnace. The ashes are sometimes removed by pulling the good coal from the back of the furnace, then dumping the ashes in the back end. The good coal in the forward end is then pushed back and the ashes in the forward end dumped. Steam jets may be used in the ash pit to soften the clinkers.

Boiler Forced Draft An artificial means for increasing the rate of combustion in a boiler by creating an excess of pressure under the fuel or a suction above it while at the same time providing for the proper supply of air to the grates as required by the rate of combustion desired. Blowers and fans are used to accomplish these results.

Boiler Fuel The combustible material supplied to the furnace of a boiler. The most commonly used solid fuels in *Titanic*'s era were anthracite and bituminous coal, although peat, lignite, wood and many kinds of refuse were also used. The liquid fuels were generally crude oil or petroleum; these eventually replaced coal as a source of fuel in all the large passenger liners due to the reduction in manpower realized by its use.

Boiler Heating Surface The area of the surfaces of the boiler that is subject to the heating action of the flames and hot gases. In fire-tube boilers there should be from 2 to 5 sq. ft of heating surface for each ihp required.

Boiler, High-Pressure A boiler designed for working pressures greater than 150lb.

Boiler Horsepower One boiler horsepower is conventionally taken as being equal to the evaporation of 34.5lb. of water per hour from a temperature of 212° Fahrenheit into dry saturated steam at the same temperature; equivalent to 33,475 BTU/h. As the efficiency of a boiler depends on many things, it follows that the accuracy of its capacity can only be determined by a boiler test.

Boiler, Scotch A fire-tube boiler which consists of a cylindrical shell with internal cylindrical furnaces which are generally corrugated to enable them to withstand external pressure. Grate bars subdivide the furnaces into two parts, the upper part for the fire and gases and the lower part for the ash pit. The hot gases pass to a combustion chamber in the back of the boiler and from there return through tubes to the front end and uptake. The water should be kept to a level above the top of the tubes and combustion chamber and occupies all the space not taken up by the furnaces, combustion chamber, tubes, stay rods, stay bolts and steam space. A large single-ended Scotch boiler as described above have as many as four furnaces, while there may be as many as eight in a large doubled-ended boiler – one in which there are furnaces and tubes at *both ends* and the combustion chambers are located midway between the ends.

Boiler, Water-Tube A boiler in which the hot gasses act on the outside of tubes through which water circulates. In connection with the tubes, horizontal drums are installed at the top and bottom. The feed-water generally enters the top drum or drums and flows down through tubes to the lower drum or drums. Convection then causes it to return through tubes, about which the hot gases pass, to the upper drum, where steam separates. The tubes may be straight, curved, or bent, but in any case the fire grates are situated below so that the flames and hot gases may pass through the tubes in rising towards the uptakes. Surrounding the furnaces and part or the whole of the drums, a casing is fitted to prevent radiation. Water-tube boilers have the following advantages over fire-tube boilers: the weight of the boiler and the contained water is less; steam may be generated more quickly; they are better suited for producing steam at higher pressures and temperatures.

Boiserie *(French)* Ornate and intricately carved paneling, often painted or gilded, used to decorate walls, doors, etc. *Boiseries* were popular in seventeenth- and eighteenth-century French interior design.

Bollards Short metal columns extending up from a base plate which is attached to a wharf or dock and used for securing the lines from a ship. The term is also applied to timber posts extending above the level of a wharf for the same purpose. The bitts on a ship are frequently called bollards, although the terms are not the same.

Bosun See 'Boatswain'.

Bottom That portion of a vessel's shell between the keel and the lower turn of the bilge.

Bottom Boards Removable boards laid in the bottom of a small boat to protect the planks of the hull from damage from persons or objects within.

Bottom, Outer The bottom shell plating in a double-bottom ship.

Bow The sides of a vessel at and for some distance abaft the stem, designated as the right-hand or starboard bow, and the left-hand or port bow.

Bow, Clipper A long, curved overhanging bow such as was characteristic of the fast wooden sailing ships built in the United States during the middle of the nineteenth century. This configuration continued in use into the early twentieth century through the waning days of steel-hulled sailing vessels. Clipper bows were also employed as late as the early 1920s in a small number of large, ocean-going steam and motorships in which a yacht-like appearance was desired.

Brackets, Beam Small steel plates, usually of triangular shape, used to fasten the deck beams to the frames at the side of a vessel. Also used to fasten deck half beams to longitudinal bulkheads, casings or coamings.

Breadth, Extreme The maximum breadth measure over plating or planking, including beading or fenders.

Breadth, Molded The greatest breadth of a vessel, measured from the heel of frame on one side to the heel of frame on the other side.

Breadth, Register The extreme breath of the vessel taken to the outside of the shell plating.

Breakwater Plates or timbers fitted on a forward Weather Deck to form a V-shaped shield against water shipped over the bow.

Breast Hook In small boat construction, the triangle-shaped piece of wood that serves as a joint connecting the keel and the bow timbers. It is mounted horizontally and resembles a shelf fitted at each end of the boat below the gunwales. A second breast hook is sometimes fitted at some distance below the top one for added strength. The term 'breast hook' should not be confused with 'lifting hook', which refers to the hook that is used to raise or lower the boat from its davits.

Bridge A term traditionally used to refer to the Navigating Bridge.

Bridge, Navigating A high, usually enclosed, transverse platform, often forming the top of a Bridge house, extending from side to side of the ship and from which may be had a good view of the forward area of the ship and the sea ahead. On the Bridge are installed the navigating instruments such as the compass and binnacle, the control for the steering apparatus and the telegraphs to the engine room. On large ships the Bridge is normally flanked by open areas of deck on either side, bounded by a bulwark on their forward and outer sides and termed the 'Bridge wings'.

Bridge House An erection or superstructure fitted about amidship on the upper deck of a ship. The officers' quarters, staterooms and accommodations are usually located in the Bridge house.

Bridge, Flying The uppermost platform erected at the level of the top of pilot house. It generally consisted of a narrow walkway supported by stanchions, running from one side of the ship to the other and the space over the top of the pilot house. A duplicate set of navigating instruments and controls for the steering gear and engine room signals were installed on the flying bridge so that the ship could be navigated in good weather from this platform. Awnings erected on stanchions and weather clothes fitted to the railing gave protection against sun and wind. The *Olympic*-class ships were not fitted with a flying bridge.

British Thermal Unit (BTU or Btu) A standard unit of heat energy. The amount of heat required to raise the temperature of 1lb of water 1°F at a constant pressure of one atmosphere.

Bulb Angle Bar An angle bar having a bulb or swell worked along the edge of one flange. In ship work it is used for frame bars, light bulkhead stiffeners and deck beams. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Bulb, Incandescent A device that produces light by means of an electric current heating to incandescence a filament enclosed in a glass chamber, from which the air has been exhausted as completely as is practicable or which has been filled with some inert gas such as nitrogen.

Bulb Plate A narrow plate, generally of mild steel, rolled with a bulb or swell along one of its edges. In ship work it is used for bilge keels, hatch coamings, built-up beams, etc.

Bulb Tee (or Bulb-T) A rolled shape, generally of mild steel, having a cross-section shaped like the letter T, with a bulb formed along the outer edge of the web. In ship work it is used for bulkhead stiffeners, deck beams, etc. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Bulkhead A term applied to any of the partition walls used for subdividing the interior of a ship into the various compartments. The main partition walls also serve as strength members of the ship's structure and as a protection against water passing from one compartment to another.

Bulkhead, After Peak A term applied to the first transverse bulkhead forward of the stern post. This bulkhead forms the forward boundary of the after peak tank and should be made watertight.

Bulkhead Bounding (or Boundary) Bar A bar used for the purpose of connecting the edges of a bulkhead to the tank top, shell, decks, or to another bulkhead. Angle bars are generally used for this purpose as both flanges are easily caulked.

Bulkhead, Coal Bunker A term applied to a coal bunker partition wall. These bulkheads, when they serve no other purpose than enclosing coal bunkers, need not be made watertight.

Bulkhead, Collision The foremost transverse watertight partition in a ship that extends at least from the bottom of the hold to the freeboard deck. The principal object of this bulkhead is to keep the water out of the forward hold in case of a collision or damage to the bow.

Bulkhead Committee That body within the British Board of Trade responsible for studying and reviewing technical and engineering data regarding watertight subdivision and bulkhead construction, and responsible for updating and promulgating regulations governing the same.

Bulkhead, Corrugated A bulkhead made from plates of corrugated metal or by flat plates alternately attached to the opposite flanges of the bulkhead stiffeners. Corrugated metal bulkheads are used around staterooms and quarters. Corrugated cargo hull bulkheads are generally constructed of flat plates alternately attached to opposite flanges of the stiffeners, but they are weak in compression.

Bulkhead Deck The uppermost continuous deck to which all transverse watertight bulkheads are carried. The term is used in connection with the method of subdividing merchant ships described in the Report of the Bulkhead Committee appointed by the president of the British Board of Trade.

Bulkhead, Engine Room A term applied to a bulkhead bounding the machinery space.

Bulkhead, Fore Peak The bulkhead nearest the stem, which forms the after boundary of the fore peak tank. When this bulkhead is extended from the bottom of the ship to the Weather Deck it is also called the collision bulkhead.

Bulkhead, Longitudinal A partition wall of planking or plating running in a fore-and-aft direction. Longitudinal bulkheads are very common on warships.

Bulkhead, Partial A term applied to a bulkhead that only extends to a portion of the way across a compartment. They are generally erected as strength members of the structure.

Bulkhead Stiffeners The beams or girders attached to a bulkhead for the purpose of supporting it under pressure and holding it in shape. These stiffening beams are usually spaced from about 2 to 4ft apart and are attached to the shell, tank top and decks by brackets or lugs. Vertical stiffeners are most common on bulkheads, but horizontal stiffeners or a combination of both may be used.

Bulkhead Stringer A term sometimes applied to horizontal bulkhead stiffeners. A horizontal girder running across and riveted to a bulkhead for stiffening purposes. The stringer is connected at the ends by a gusset bracket to the side stringers or shell.

Bulkhead, Transverse (1) A partition wall of plating running in an athwartship direction across the whole breadth of a ship. The principal function of transverse bulkheads of this type is to divide the ship into a series of watertight compartments so that any rupture of the shell will not cause the loss of the vessel. Transverse bulkheads also serve as efficient strength members and are important in preserving the transverse shape of a vessel. (2) Also, any partition wall of plating or planking running in an athwartship direction across any portion of the ship. In either form, these bulkheads also serve the purpose of subdividing the cargo space and quarters into compartments of desirable length.

Bulkhead, Watertight A partition of plating reinforced where necessary with stiffening bars and capable of preventing the flow of water under pressure from one compartment to another. To do this, all seams, butts or connections of the plating must be efficiently caulked and the strength of the structure must be sufficient to stand up under pressure.

Bull's-Eye Light See 'Light, Bull's-Eye'.

Bulwark The strake of light shell plating or the side planking above a Weather Deck. It helps to keep the deck dry and also serves as a guard against losing deck cargo or men overboard. Where bulwarks are fitted it is customary to provide openings in them which are called freeing ports, to allow the water that breaks over to clear itself. Bulwarks may be fitted with hinged or removable doors to facilitate the loading of cargo or supplies, or the boarding of passengers, through the bulwarks.

Bunkers, Coal The spaces or compartments of a ship in which is stowed the coal used as fuel for the boilers.

Buoy A floating object that is moored or anchored so that it remains at one place. Buoys are used for marking the place on the water where a ship is sunk, where reefs are below, where the edges of the channel are, or to provide means for mooring a ship at a designated position within a harbor.

Buoy, Life Ring See 'Life Buoy'.

Buoyancy The supporting effort exerted by a liquid (usually water) upon the surface of a body wholly or partially immersed in it.

Buoyancy Tanks Airtight compartments in a ship's small boats or lifeboats to provide buoyancy should the boats become filled with water.

Burden A vessel's carrying capacity expressed in long tons. (*Archaic*: burthen.)

Burgee A triangular, usually swallow-tailed, flag used as a distinguishing pennant by yachts and merchant vessels. In some cases it bears the name of the vessel, in others the initials or some device of the company or firm owning or operating the vessel.

Burthen See 'Burden'.

Bus Bar An electrical conductor. Specifically, a metal bar of low electrical resistance commonly used on the rear of power switchboards for carrying current between electrical apparatus.

Buttock The rounded portion of the lower stern. This term is also applied to vertical longitudinal sections on the lines plan.

Buttocks The traces formed by the intersections of longitudinal vertical planes parallel to the central longitudinal vertical plane of the ship, with the forward and after surface of the ship's hull. These traces when occurring in the forebody are called bow lines, and when in the after body, buttock lines. However, the term buttocks is often used to denote both bow and buttock lines.

Butts, Shift of The arrangement of the butt (end) joints in plating. These joints in shell plating should be so shifted that the adjacent strakes of plating have their butts at least two frame spaces apart. Also the butts in any frame space for the complete number of strakes should be made as few as possible, say every six or seven strakes. See Joint, Butt (2).

Butt Straps A strip of plate serving as a connecting strap between the butted ends of plating. The strap connections at the sides are called seam straps.

Cabin A room containing one or more berths for passenger or crew use. As a general term, refers to such rooms irrespective of class, although in this text is used to refer to Third Class and crew accommodations only.

Cable, Anchor That which connects a ship to its anchor. Anchor cables are made of hemp, steel wire, or links forged from iron or steel, and must be of considerable length in order that the ship exerts as lateral a pull as possible on the anchor in order to ensure its holding power.

Cable Holder On an anchor windlass or chain cable capstan, the drum around which the chain cable turns, and which is fitted with projections called 'whelps' which engage every other link. Also called a 'wildcat' *(chiefly US Navy).*

Cable (Length) A rough measure of distance equal to about 600ft.

Caulk To make watertight by swaging the sight edges of plates or shapes riveted in place. In woodwork, to make watertight by filling the seams between planks with oakum and pitch or tar.

Caulking Iron A tool used for driving oakum into seams.

Camber The rounding up or arching in an athwartship direction the Weather Decks of ships for the purpose of draining any water that may fall on them to the sides of the ship where it can be led overboard through scuppers. This arching or rounding up is called the 'camber', and is expressed in inches in connection with the greatest molded breadth of the ship in feet. Also called 'round of beam'.

Candlepower The practical unit of the luminous intensity of sources of light.

Cant (1) A term used by shipwrights to signify an inclination of an object from a perpendicular. (2) To turn anything so that it does not stand perpendicular or square to a given object. (3) (*Ship joinery*) The coaming of a wood partition bulkhead, laid down and affixed to the deck.

Capacity The measure of power to receive or contain, or the measure of ability to exert power, as in a cargo hold of five hundred tons capacity or a crane of ten tons capacity.

Capstan A device operating in a horizontal plane for exerting a hauling force on a mooring line, warping line or hemp anchor cable. A capstan consists of a cleated drum or cylinder revolving on a vertical spindle, around which several turns are taken of the line that is to be hauled on. As the capstan drum turns, the line is hauled on. On *Titanic*, capstans were fitted for warping purposes, and were steam powered.

Cargo Merchandise or goods accepted for transportation by ship.

Casing, Boiler Room The partition or walls enclosing the space above the boiler room in the way of the boiler hatch. This casing should form a trunk of sufficient size to allow the installation and removal of the boilers, and also, when the boilers are in position, to accommodate the funnel uptakes and ventilator and/or fidley trunks that lead to the boiler room. Doors fitted in the casing at various deck levels give access to gratings and ladders leading into the boiler room. The top of the casing should project well above the Weather Deck where there is no superstructure and should be carried up through the superstructure where one is erected.

Casing, Deck Piping Covering plates built over exposed deck piping for protection.

Casing, Engine Room The partitions or walls enclosing the space above the engine room in the way of the engine room skylight and hatchway. The casing forms a trunk suitable for access, light and ventilation. At the top of the casing a skylight with hinged covers is fitted through which the heat from the engine room escapes. Doors are fitted in the casing at the deck levels which give access to gratings and ladders leading down into the engine room. Care should be taken that the engine room casing encloses a space sufficiently large to provide for installing the engines and for lifting the cylinder covers where reciprocating engines are used. Portable strong beams are fitted in the casing trunk to compensate for the opening and for convenience in lifting covers, etc. The top of the casing should project well above the Weather Deck where there is no superstructure and should be carried up through the superstructure where one is erected.

Castings Metal frames, gears, housings, etc., made by pouring molten metal into forms and allowing it to cool. Stems, stern frames, struts, stern tubes, bitts, chocks, turbine casings, cylinder casings and liners, engine bed plates, gear wheels, etc., are some of the castings common in ship work.

Caulkers (1) In steel ships, workmen who secure the water- and oil-tightness of joints by swaging the metal into the openings between plates or other parts. This work is generally done with suitable tools, either by hand, or driven by compressed air. (2) In wood ships, workmen who open the seams between the planks and drive in oakum or cotton to make them watertight.

Cavitation See 'Propeller Cavitation'.

Center of Buoyancy The center of gravity of the submerged portion of a vessel.

Center of Gravity The point at which the combined weight of all the individual items going to make up a vessel's total weight may be considered as concentrated.

Chain, Close-Link Sometimes known as short-link chain. Chain in which the links are so short relative to their width that studs cannot be fitted.

Chain Compressor A forging fitted below the upper deck and pinned at one end to the deck casting at the head of the chain pipe or to the ship's structure nearby. At the other end of the shank an eye is worked for the attachment of a tackle. The controller is so located that the application of force by mechanical means at the eye controls or stops entirely the passage of the chain by forcing it against the chain pipe.

Chain Controller A device located on deck between the windlass and the hawse pipe in line with the anchor chain. The compressor consists of a heavy cast or forged bed, shaped to receive a link of the anchor chain, and a lever so arranged as to force the chain into the bed at the will of the operator. This device is termed a chain compressor in the merchant service.

Chain Hoist A differential block-and-chain fall operated by an endless chain. Chain hoists are used for raising heavy weights about a shop and weights like cylinder heads, auxiliaries, etc., aboard ship.

Chain Lockers Spaces or compartments intended for stowage of the anchor chains. They are usually located in the fore hold directly underneath the windlass with chain pipes connecting them to the anchor deck under the wildcats.

Chain Pipe A pipe generally of cast iron, though sometimes of wrought iron or mild steel, leading from the upper deck bolster to the chain locker for the purpose of handling the anchor chain. At its lower end it is fitted with a half round, or so shaped as to prevent the chafe of the chain when running out. Chain pipes are usually set at an angle to the vertical in order to minimize the noise made by the chain swinging against the chain pipe with the vessel's roll.

Chain, Stud-Link Chain in which each link has a short distance piece (known as a stud) worked at its mid-length at right angles with its major axis. Stud links are used for anchor cables primarily to ensure that the links of the cable properly feed onto and are engaged by the whelps of the cable holder. Additionally, the studs help maintain the shape of the links when the cable is placed in tension.

Chain Stopper A device used to secure the chain cable when riding at anchor, thereby relieving the strain on the windlass, and for securing an anchor in the housing position in the hawse pipe. Stoppers differ widely in construction. For smaller cables they may be of rope, usually hemp, with a stopper knot or an iron toggle in the outer end and a lanyard for lashing to the cable. For larger cables, wire rope is used in lieu of hemp, while for the largest cables the stoppers are of heavy chain fitted with slip hooks and turnbuckles for adjusting and for equalizing the strain when more than one stopper is attached to a cable. According to its use, a chain stopper is termed either a 'riding stopper' or a 'housing stopper'. The inner end of the stopper is attached to a deck pad by means of a shackle or lashing.

Chain Tierers The men who stow the chain cables as they are paid down into the chain locker. The chains are arranged regularly in symmetrical long tiers, or 'flakes' in a fore-and-aft direction. The tierers use chain-hooks and hook-ropes and in some cases tackles in performing their work. Some cables are too heavy to be handled by tierers and are stowed in deep and narrow lockers, where the chain is allowed to assume any position as it is paid down. See 'flake'.

Chamfer To cut off the edge or corner of; to bevel.

Chandler An individual or firm handling provisions, outfit, or other commodities for a ship's use.

Channel Bar A rolled shape, generally of mild steel, having a cross-section shaped like that of an I-beam from which both flanges on the same side of the web have been cut even with that face of the web. In ship work it is used for frames, deck beams, bulkhead stiffeners, etc. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Chart In general, a map showing the contour of coasts, the location of shoals, rocks, soundings, etc., the depth of water, and the location of navigational aids such as buoys, lighthouses, etc.

Chart House A deckhouse on or near the bridge, serving the same purpose as a Chart Room.

Chart Room A room adjoining the bridge, provided with stowage for navigation charts and facilities for their use.

Chock (1) Oval-shaped castings, either open or closed on top, and fitted with or without rollers, through which hawsers and lines are passed. (2) Blocks of wood used as connecting or reinforcing pieces, to blocks of wood used as filling pieces. (3) Supports that carry the weight of the life boats when the lifeboats are stowed on deck and their weight is not being borne by the davits.

Chronometer, Marine A timepiece mounted on gimbals in a glass-covered case to keep it horizontal and to preserve it from vibration, dust, drafts, and fluctuations of temperature. The movement (mechanism) is of a superior construction, having adjustments and compensations for temperature. While generally designed to run for fifty-six hours, it is wound daily at a stated hour and is not regulated. The instrument is set as accurately as possible and its accuracy observed in an observatory. A certificate of rating is issued, showing its rate of gain or loss and this cumulative error must be considered when observing the time.

Chute A ramp or slide with low sides, constructed of either steel or wood, for rapid loading or unloading of mail, coal, baggage, etc. *(Antiquated sp: 'shoot'.)*

Circuit Breaker An electric switch equipped with a carbon break and a trip for opening.

Clack A simple form of check valve consisting of a flap suspended vertically or nearly vertically from hinges at top, with the purpose of limiting the flow of liquids to one direction only.

Clamp In small boat construction, a reinforcing plank installed along the inboard edge of the gunwale.

Classification Society An institution that supervises the construction of vessels throughout under established rules, tests all materials for hulls, machinery and boilers; proof-tests all anchors and anchor chains and issues Certificates of Classification which are a builder's receipt, an owner's guarantee, an underwriter's authority and a shipper's business guide.

Cleading An external protective lining.

Clear Hawse A vessel is said to have a 'clear hawse' if, when moored, its cables lead off to the anchors on their respective sides clear of each other, i.e., without their cables crossing.

Clench To fasten with a copper nail by hammering the head over after driving the nail completely through the planks or timbers to be fastened.

Clinker-Built A wooden boat constructed with overlapping planks that give a stepped appearance to the hull.

Clinometer An instrument for measuring the degree of list to port or starboard.

Cluster Light A portable lamp in which three or more light bulbs are fitted beneath a single reflector, and used for providing auxiliary light on or below decks.

Coal Passer A Trimmer assigned to work in the stokehold to remove the coal from the bunkers and supply it to the Firemen. See 'Trimmer'.

Coaming, Bulkhead A term applied to a strake of plating running across the top and bottom of 'tween deck, poop, bridge and forecastle bulkheads. The coamings are usually made thicker than the remaining plating and serve the function of top and bottom supports.

Coaming, Hatch A frame bounding a hatch for the purpose of steering the edges of the opening and forming the support for the covers. In a steel ship it generally consists of a strake of strong vertical plating completely bounding the edges of a deck opening. In wood ships this coaming consists of heavy timber forming a frame around a hatch.

Coaming, House The narrow vertical plates bounding the top and bottom of a deck house. These plates are made somewhat thicker than the side plating and form a frame for the base and top of the house. Also applied to the heavy timber forming the foundation of a wood deck house.

Cock A mechanical device for opening or shutting off the flow of a liquid through a pipe line. A cock differs from a valve in that the liquid flows through a channel bored through the tapered plug forming the cock and in no case is it necessary to turn the handle more than a quarter turn to open it fully. The handle fitted to the plug, usually a simple lever, is arranged so that it is aligned with the flow of liquid when open, and is at a right angle to the flow when shut, giving visual indication as to whether the cock is opened or closed.

Cofferdams Void or empty spaces separating two or more compartments for the purposes of insulation, or to prevent the liquid contents of one compartment from entering another in the event of the failure of the walls of one to retain their tightness.

Coir The tough, waterproof fibers from the outer husk of the coconut. Used for hawsers, mats to reduce slippage on deck, and for the woven coverings around handrails.

Combination In small boat construction, the stem post, keel and stern are considered as a single member.

Come About With a rowboat or an engine-driven vessel, to 'come about' generally means to swing the bow around to effect a complete reversal of direction.

Commutator A copper cylinder composed of insulated segments mounted on the shaft of an electric motor or generator. The insulated segments are connected to the armature coils and are so arranged as to change the connections of the armature coils with the carbon brushes as the armature rotates.

Companion or Companionway A hatch or opening in a flat, deck or house top to provide access, principally for the passage of crew or passengers.

Condenser A chamber of rectangular or cylindrical shape whose function is to convert the exhaust steam from the engines and auxiliary machinery into water.

Condenser, Auxiliary A condenser for the auxiliary machinery such as pumps, refrigerating machinery, generator engines, winches, steering engines, windlasses, etc. Often intended primarily or only for use when the main condensing and feed water return plants are idled, such as when the ship is in port.

Courtesy Flag The national ensign of the country whose port a ship is entering or in whose port a ship is anchored, moored or berthed. It is traditionally flown entering port and during daylight hours until the ship sails.

Cover, Boat A piece of canvas used as a cover for a small boat when it is not in use.

Coxswain A petty officer or seaman who steers or has charge of a small boat. Pronounced 'coxs'n'.

Crane A machine used for hoisting and moving cargo, pieces of material or portions of structures or machines that are too heavy to be handled by hand or that are heavy enough to make handling by hand uneconomical.

Crane, Jib A boom or arm fitted to swing in sockets attached to a wall or column. The boom in this type of crane is generally fixed in a vertical direction but free to move horizontally.

Crow's-Nest A lookout station attached to or near the head of a mast.

Crutch (1) A support or boom. (2) The jaw of a boom or gaff. (3) A U-shaped metal fitting on a swivel, fitted in the gunwale and used to hold an oar in place and to act as a fulcrum when rowing. On *Titanic*'s lifeboats, crutches were used only for the steering oar at the stern. Also see 'Oar Lock'.

Cutter This term has many different meanings; in *Titanic*'s case; the best definition is a 'ship's boat'. On *Titanic*, the two 25ft boats carried in the forward-most davits were designated 'emergency cutters', and were kept permanently swung out and ready for use.

Davit A crane used to lower and raise lifeboats and sometimes anchors. The rotary, or radial, davit (not used on *Titanic*) consists of a vertical pillar, round in section, with the upper portion bent in a fair curve and having sufficient out-reach to clear the side of the ship plus clearance. Each lifeboat has two davits, one near its bow and one near its stern; and they both rotate, lifting the boat from its stowage position on the deck, and swinging it clear of the side. This type of davit is usually stepped in a socket attached to the side of the vessel or on the first deck below the boat deck near the side. At the boat deck level it is held in place by a keeper or bearing. The quadrant type, as fitted to *Titanic*, consists of a pair of curved arms with a quadrant-shaped base, geared to a toothed rack; the arms rotate about a horizontal axis, with the davit arms swinging outward in an athwartships plane.

Davit Cleat A cleat used for fastening the end of the boat falls. It is generally seized or lashed to the davit, or otherwise securely fastened.

Deadlight (1) A port lid or cover. (2) A metal shutter fitted from within to protect against the breakage of the glass in a fixed or port light.

Dead Reckoning The process of calculating a ship's position by taking the last known position and factoring in the ship's speed and distance traveled since the last known position, along with the speed and direction, or 'set', of any prevailing current. The term takes its name from 'deduced reckoning', which was abbreviated '*de'd reckoning*' on early charts.

Deadrise The angle which the straight portion of the bottom floor of the midship section makes with the base line. It is expressed by the number of inches' rise above the base line in the half beam of the vessel.

Deadwood In small boat construction, refers generally to any stout timber used to build up a structural member to add strength or to extend it out to a desired point. In the case of *Titanic's* lifeboats, the term 'deadwood' was used to refer to the stout timbers fitted over the scarf joint between the keel and stem post, and over the keel and stern post, to give added strength.

Deck A deck in a ship corresponds to the floor in a building. It is the plating, planking, or reinforced concrete covering or any tier of beams above the inner bottom, forming a floor, either in the hull or superstructure of a ship.

Deck, After A deck abaft the midship portion of a vessel.

Deck, Boat A superstructure deck provided for the stowage of the life boats; generally, the uppermost deck of the ship.

Deck Bolts The bolts that are used in fastening planking to the deck beams.

Deck, Bridge The deck forming the top of a bridge house, or partial superstructure. On *Titanic*, this was B Deck. Not to be confused with the 'Navigating Bridge'.

Deck, Bulkhead The uppermost continuous deck to which all the main transverse watertight bulkheads are carried. Ideally, this deck should be watertight in order to prevent any compartment that is open to the sea from flooding the one adjacent to it, however in practice, in commercial ships this is not practical. On *Titanic*, this was E Deck, known also as the 'Upper Deck'. Also see 'Upper Deck'.

Deck, Caulked A steel deck having the edges of such plating and bars as are necessary to secure watertightness caulked. It is applied to a wood deck when the seams between the planking are filled with cotton or oakum and payed with marine glue. Where planking is laid over a steel deck it is advisable to caulk the planking only because any leaks in the wood covering would be held by the steel deck causing the wood to rot from beneath.

Deck, Canvas-Covered To secure watertightness, wood decks and wood roofs that are not caulked are often covered with canvas. After the canvas is laid and stretched taut it is given a coat of paint.

Deck Cargo Cargo carried on deck.

Deck Chair An item of weatherproof furniture designed for the use of passengers and for easy stowing on liners. Developed from the hammock, and originally consisting of canvas stretched on a collapsible wooden frame. Luxury liners eventually had cane-seated or fully slatted chairs of mahogany or teak which could similarly be collapsed. Sometimes referred to as a 'steamer chair'.

Deck Covering or Decking Various compositions and materials have been used for covering decks. The light upper Weather Decks (mainly the tops of freestanding deckhouses) are commonly covered with canvas and then given a coat of paint. The heavy steel Weather Decks, when not planked over, are often covered with a composition which serves as a protection to the steel and makes a better surface for working. The decks in the living quarters are usually covered with linoleum or some composition with the object of protecting the steel and of providing a level walking surface that is easily kept clean and sanitary. In addition to the above some of the compositions are insulating and fireproof as well as elastic and neat appearing.

Deck Dowels or Plugs Cylindrical plugs used to cover the heads of the bolts fastening the deck planking.

Deck, Forecastle A term applied to a deck worked from the stem aft over a forecastle erection. Typically the uppermost deck over the bows of the ship. Also see 'Forecastle'.

Deckhouse A partial superstructure that does not extend from side to side of a vessel like a Bridge, Poop or Forecastle Deck.

Deck, Lower The lowest continuous deck in two- and three-deck vessels, and the next to lowest in vessels having four or more decks. On *Titanic*, this was G Deck.

Deck, Main The principal deck of a ship. It is usually the one next below a complete top or Upper Deck; may be synonymous with the Upper or Bulkhead Decks.

Deck, Orlop A partial or non-continuous deck interrupted by the machinery spaces. Often the lowest deck in a ship having four or more decks.

Deck Planking See 'Deck Sheathing'.

Deck Plating The steel plating covering a deck.

Deck, Poop A deck worked from the stern forward over a poop erection.

Deck, Promenade An upper superstructure deck on a passenger ship designed as a promenade for the passengers.

Deck, Shade A very light deck fitted from bow to stern to provide protection against the weather. The sides below this deck are fitted with openings.

Deck Sheathing The wood planks used to cover a steel deck. This term is sometimes also used in reference to 'Deck Coverings'.

Deck, Shelter A term with various meanings dependent upon the ship type and classification: (1) On very large ships, the highest continuous deck running the full length of the vessel; on *Titanic*, this was C Deck. (2) A deck similar to an Awning Deck, fitted from stem to stern, but built on a very light superstructure.

Deck, Tongue-and-Groove A deck covered with thin, machined planks and generally used on the upper light decks of vessels. Tongue-and-groove decks are usually covered with canvas after which a coat of paint is applied. The term applies to the method of construction and not a specific deck within the ship.

Deck, Tonnage The tonnage deck in vessels having three or more decks to the hull is the second deck from the keel, and in all other cases it is the Upper Deck of the hull. If the second deck from the keel consists of several partial decks extending with breaks from stem to stern, the line of that course of decks must be taken as the tonnage deck; and if the partial decks are at different heights, the line of the lowest will be taken as the tonnage deck and the head room above such line under the higher will be measured.

Deck, Trunk The top of a fore-and-aft trunk erected on the Upper Deck.

Deck, 'Tween Any deck below the Upper Deck. Also, generally, the space between decks.

Deck, Upper Generally, in ships having two or three decks, the uppermost continuous Weather Deck. Where the highest continuous deck is an Awning, Shade or Shelter Deck, these terms should apply, and the next applicable deck below may be called the main or Upper Deck. In British merchant shipbuilding practice, this term was generally applied to the Bulkhead Deck. [*Note: In general terms, 'upper deck' or 'upper decks' were sometimes used to refer to those decks that gave direct access to the outside of the ship. Typically this would include the Boat Deck, Well Decks, Promenade Deck, etc.*]

Deck, Weather The Upper, Awning, Shade or Shelter Deck or the uppermost continuous deck exclusive of the Forecastle, Bridge and Poop Decks that is exposed to the weather.

Deck, Well A recessed deck on a merchant vessel, located between the forecastle and a long poop, or between the Forecastle or Poop Deck and a continuous bridge house amidships.

Declination See 'Variation'.

Declivity Deviation from a horizontal line; gradual descent of surface; inclination downward.

Deep Tank A tank extending from the bottom of a vessel or from the top of the inner bottom up to or higher than the lower deck. Deep tanks are commonly fitted either forward or abaft the machinery space in cargo vessels. They are fitted with hatches so that they may be used for cargo when the ship loaded, as well as for ballast water when the ship is riding light.

Deep Water Line The water line at which a vessel floats even carrying the maximum allowable load.

Depth by Lloyd's Rules The depth at the middle of length from the top of keel to the top of beam at side of uppermost continuous deck, except in Awning or Shelter Deck vessels, where it may be taken to the deck next below the Awning or Shelter Deck, provided the height of 'tween decks does not exceed 8ft. When the height of 'tween decks exceeds 8ft the depth is to be taken from the top of keel to a point 8ft below the Awning or Shelter Deck.

Depth Molded. The vertical distance from top of beam of uppermost strength deck at side of vessel amidship to top of keel.

Depth, Register The register depth should be taken from the underside of the Tonnage Deck plank midship to the ceiling in the hold, average thickness, at the side of the keelson, in a direction perpendicular to the keel, which may be done by a square placed upon the upper side of the keelson. If the vessel has a third deck, then the height from the top of the tonnage deck plank to the under side of the Upper Deck plank shall be accounted as the height under the spar deck.

Derrick An apparatus designed to hoist heavy weights. The general design of a derrick is similar to that of a post crane except that the boom is hinged at the heel which allows it to be set at any angle with the post. The post of a derrick usually rotates with the boom.

Derrick, on a ship A spar or a boom, one end of which is stepped in a pivot bearing on the lower portion of a vertical post erected on the deck of a ship or on a pedestal fitted to the deck at the foot of the vertical post. A hinged connection fitted to the pivot bearing allows the boom to be inclined at any angle with the post while the pivot permits it to be revolved. The derrick is fitted with ropes, guys and tackles and is used for transferring cargo from and into the hulls. Unlike most derricks on land the derrick post itself (frequently the mast) does not revolve.

Deviation The compass error resulting from the influence of the iron and steel in the ship.

Dished Shaped in the form of a shallow trough.

Displacement The amount or quantity of water displaced by a floating vessel. It exactly equals the weight of the vessel itself with whatever is on board at the time at which the displacement is recorded. Displacement may be expressed either in cubic feet or tons; a cubic foot of sea water weighs 64lb and one of fresh water 62.5lb, consequently one ton is equal to 35 cubic ft of sea water of 35.9 cubic ft of fresh water. The designed displacement of a vessel is her displacement when floating at her designed draft. In merchant vessels this is generally taken with full cargo, fuel, stores and water on board. In the case of naval vessels it corresponds to the vessel complete with full supply of ammunition, and two-thirds full supply of fuel, stores and water.

Displacement Curve A curve showing what the displacement of a vessel would be when floating at any particular draft.

Displacement, Volume of The volume of water displaced by a vessel. In the English system of units the volume of displacement is given in cubic feet and equals thirty-five times the displacement in salt water or thirty-six times the displacement in fresh water.

Distiller A chamber in which steam vapor from an evaporator is condensed, forming fresh water for drinking and other purposes. It consists essentially of a chamber into which the steam vapor enters and is condensed by a pipe coil through which cold sea water circulates.

Dividers A two-pronged, hinged instrument for measuring on scales or 'walking off' distances on a chart.

Dog (1) A holding device used on doors, hatch covers, sidelights, or other hinged parts of a ship to fasten them shut. (2) An L-shaped metal bar of round iron used on a bending slab to hold the wedges and finished pieces to the slab. (3) To fasten or clamp in place by the use of dogs.

Door, Cargo A door, usually composed of two or more parts, fitted in the side or an upper bulkhead of a vessel for the purpose of providing access through which cargo may be trucked.

Door, Dutch A door built in two independent sections, one above the other, so that the upper half may be open while the lower half is closed. These doors are commonly used for access to galleys.

Door, Gangway A door fitted in the side of a vessel to provide access for a gangway.

Door, Horizontal or Vertical Sliding A door so constructed and operated that it can be slid horizontally into position in the case of horizontal doors, and vertically into position in the case of vertical doors. Such doors are usually watertight and are fitted with shafting and bevel gears or other means so that they can be closed from the weather or Upper Deck.

Door, Watertight A door so constructed that when closed it will prevent water under pressure from passing through. The simplest and most-common type consists of a steel plate, around the edges of which a frame of angle bar is fitted, having a strip of rubber attached to the flange that is parallel to the door plate. The strip of rubber is compressed against the toe of the flange of an angle iron door frame by dogs or clamps.

Door, Weathertight Outside doors on the Upper

Decks, designed to keep out the rain and spray.

Double Bottom The bottom space between the inner and outer skins of a vessel. Also applied to indicate that a ship has a complete inner or extra envelope of watertight plating. A double bottom is usually fitted in large ships extending from bilge to bilge and nearly the whole length fore and aft.

Double Bottom, Cellular A double bottom that is divided into numerous rectangular compartments by the floors and longitudinals.

Draft (of a vessel) The depth of a vessel below the waterline, measured vertically to the lowest part of the hull, propellers or other reference points.

Draft Marks The numbers which are placed at the bow and stern of a vessel to indicate how much water she draws. These numbers should be as near the stem and stern as possible and should be 6in high and spaced 12in apart vertically.

Draft, Mean The mean of the drafts measured at the bow and the stern, or in the case of vessels with straight keels the draft measured at the middle of the waterline length.

Dunnage (1) Loose wood or waste material placed in the hold of a vessel for the protection of the cargo from dampness. (2) A sailor's kit or personal belongings.

Dynamo See 'Generator, Electric'.

Edge, Sight That edge of a strake of shell plating which laps outside another strake and is, therefore, in plain sight.

EHP See 'Horsepower, Effective'.

Electrolier From the word 'electric', in imitation of the word *chandelier*, used to describe a branching frame (often of ornamental design) to support electric illuminating lamps.

Engine, Reciprocating An engine designed to convert the pressure of live steam into work. This is accomplished by means of the backward and forward motion of a piston from top to bottom, or end to end of a cylinder as the result of steam being alternately admitted to each end of the cylinder and the expanded steam exhausted from the other end. The straight-line motion of the piston is communicated to the piston rod to which it is directly attached and is then transformed into rotary or circular motion by means of suitable mechanism.

Ensign The national flag of a country flown at sea. It may be the same as the version flown on land, as with the US flag, or it may be a variant thereof, as with the British Ensign.

Ensign Staff A flag pole erected at the stern of a vessel for purposes of flying the ship's ensign.

En Suite *(French)* (1) Of the same style or design as the surrounding room; as part of; in a series or set. For example – a room and its furniture that were decorated *en suite* – both room and furniture being decorated in the same design, or a fireplace decorated *en suite*. (2) Having a private bath room accessed directly from the stateroom or off a private connecting hallway. (3) Located within the room.

Evaporator An auxiliary for supplying fresh water to make up the loss in boiler feed-water occurring from steam leaks in pipe joints and stuffing boxes, use of the whistle, opening the safety valves or from other causes. Cumulatively, these losses are appreciable and the evaporator must supply the 'make-up' feed in order to avoid the use of salt water. A typical evaporator consists of a chamber into which boiler steam is passed in coils or nests of tubing. Salt water is admitted into the chamber and is converted into steam which is then passed over to the condenser or low pressure receiver. The water condensing in the coils by the loss of heat is returned to the feed supply.

Expansion Joint A joint which permits linear movement to take up the expansion and contraction due to changes in temperature or movement within a structure.

Eye A hole through the head of a needle, pin, bolt, etc., or a loop forming a hole or opening through which something is intended to pass, such as a hook, pin, shaft or rope. Familiar examples are an eye at the end of a tie bar in a bridge truss, an eye at the end of a rope as the parts of shrouds and stays that pass over a masthead. A 'worked eye' is one having its edge rounded off like a ring, while a 'shackle eye' is drilled straight through, permitting an inserted bolt or pin to bear along its entire length.

Eye Plate See 'Pad Eye'.

Eyes The forward end of the space below the Upper Decks of a ship which lies immediately abaft the stem, where the sides approach very near to each other. The hawse pipes are usually run down through the eyes of a ship.

Eyes of the Ship *(slang)* The area of the Forecastle Deck farthest forward, over the anchor hawse holes. Lookouts stationed here are sometimes said to be stationed 'in the eyes of the ship'.

Fair Curves Curves which do not in any portions of their entire lengths show changes of direction such as to mark those portions as out of harmony in any respect with the curves as a whole or with the other portions of the curve.

Fairleads Fittings that are used to change or preserve the direction of a rope or chain so that it is delivered fairly to a sheave or drum. Large fairleads in the shape of a drum on a vertical shaft are used to deliver a hawser coming through a chock or mooring pipe to a winch or windlass. Fairleads are also used with the steering leads, in which case they may be fittings with small sheaves or annular rings. With steering leads, the fairleads are generally more for preserving than changing the line of the ropes.

Fake (1) One of the circles or windings of a cable or hawser, as it lies in a coil; a single turn or coil; (2) To coil line or cable by winding alternately in opposite directions, in layers usually of zigzag or figure-eight form, in order to prevent twisting when running out. See 'Flake'.

Falls By common usage the entire length of rope used in a tackle, though a strict adherence to the term would limit its application to the end to which the power is applied. The end secured to the block is called the standing part and the opposite end, the hauling part.

Fantail The stern overhang in vessels in which the uppermost decks are round or elliptical at their after ends, and which extend well abaft the after perpendicular.

Farad The unit of electrostatic capacity. It represents the capacity of a conductor that requires 1 coulomb of electricity to charge it to the potential of 1 volt.

Fathom A unit of length used in measuring cordage, depths, etc. The length varies in different countries, being 6ft in Great Britain and the United States. This is roughly obtained by extending both arms.

Feather-and-Groove See 'Tongue-and-Groove'.

Feed-Water See 'Boiler Feed-Water Make-Up'.

Fender This term is applied to various devices fastened to or hung over the sides of a vessel for the purpose of preventing rubbing or chafing.

Ferring, or Furring Strips of timber or boards fastened to frames, beams, etc. to provide points for the attachment of sheathing, ceiling, cleading, flooring, and interior joinery.

Fidley Also spelled 'fiddley'. A term applied to the top of a boiler casing. Through it pass the uptakes and boiler room ventilators. The top around the stack and cowls is fitted with gratings made of bar steel, with metal covers that can be closed when the weather is very bad.

Fidley Gratings Gratings made of bar steel and fitted over the top of the boiler hatch.

Fidley Trunk A trunk constructed within the boiler casing for the purpose of exhausting hot air and other contaminants from the boiler room.

Filter, Feed-Water An apparatus designed for the removal of oil and grease from boiler feed-water. It consists of a suitable connection and a vessel or container in which is placed the filtering material. This material may be gravel, sand, broken stone, etc., or it may be cloth, sponge or similar material. Water may be led through the apparatus by gravity or forced through under pressure. In the latter case provision must be made for relief from excessive pressure should a stoppage in the filter occur.

Fireman A skilled Engine Department rating whose primary job is to maintain the fires within the furnaces of a boiler and to ensure that the boiler maintains the steam pressure required to drive the main engines and other machinery.

Firing Aisle See 'Stokehold'.

Fitment Any item furnishing or equipping a room.

Flake A flat layer, or fake, of a coiled cable. See 'Fake'.

Flam A term often used to express the same meaning as flare, but more properly used to denote the maximum curl or roll given to the flare at the upper part of the hull.

Flare The outward sweep of the hull from the central vertical plane as the section rises from the waterline to the rail.

Flat A partial deck built without any camber.

Flat of Bottom That portion of a ship's bottom without rise, or having a rise without curvature, or nearly so.

Floor A plate placed vertically in the bottom of a ship, usually on every frame and running athwartship from bilge to bilge.

Foot Spar A spar mounted athwartships near the bottom of a small boat for use by the oarsmen. The oarsmen brace their feet against the foot spar(s) when rowing.

Fore A term used in indicating portions of that part of a ship at or adjacent to the bow. Applied to that portion of the ship lying between the midship section and stem as in 'fore body'. Also to portions or parts of the ship lying between the midship section and stem as in 'fore hold' and 'foremast'.

Fore-and-Afters The portable beams running fore and aft in a hatch which support the covers and which, in turn, are supported by athwartship cross beams. Also, a term sometimes used to refer to a carling or other permanent short longitudinal structural member.

Forebody That portion of the ship's body forward of the midship section.

Forecastle (1) A short structure at the forward end of a vessel formed by carrying up the ship's shell plating a deck height above the level of her uppermost complete deck and fitting a deck over the length of this structure. The after end of the forecastle may or may not be closed by a transverse bulkhead. (2) The name given to the crew's quarters on a merchant ship when they are in the fore part of the vessel. Often abbreviated 'fo'c'sle', and pronounced 'fok-sil'.

Forecastle Sheer Strake The strake of outside plating adjacent to the Forecastle Deck.

Forefoot (1) A term designating the approximate intersection of the curved portion of the stem and the keel. (2) That point in the forward end of the keel about which the vessel pivots in an endwise launching.

Foremast In a steamship having two masts, the mast located toward the bow of the ship.

Forestay A rope, whether hemp or wire, that supports a mast in a forward direction.

Forward In the direction of the stem.

Forward Perpendicular A line perpendicular to the base line and intersecting the forward side of the stem at the designed waterline; or, with ships having other than a plumb stem, a line perpendicular to the base line and intersecting the forward side of the stem at the upper, or bulkhead deck.

Founder To become filled with water and sink.

Frame A term generally used to designate one of transverse ribs that make up the skeleton of a ship. Where the structure is built up of a relatively small number of strong transverse webs or belt frames and a relatively large number of smaller fore-and-aft bars, the fore-and-aft bars are called the frames. The frames act as stiffeners, holding the outside plating in shape and maintaining the transverse form of the ship.

Frame, Built-Up Those frames which are made by riveting together a combination of shapes, or shapes and plates.

Frame, Cant A frame not square to the longitudinal centerline. Those found in the overhanging part of the stern of the vessel are typically made from bulb-angle and radiate in a fan shape from the transom floors to which they are attached through brackets and lugs or clips.

Frame, Reverse A bar riveted to the upper edge of a floor plate or the web or inner flange of a frame. The fore and aft flanges of reverse bars when riveted to frames are toed in the opposite direction to the flange of the frame. One advantage of using frames and reverse frames over solid frames is that the reversed frame may be stopped at or a little above the bilge where the design will permit. A common design is to run all reverse frames in the bow and stern to the upper, forecastle or Poop Deck as the case may be and to run the alternate reverse frames to the Upper Deck in the main body.

Frame, Solid Those frame which are formed of a single bar of bulb-angle or channel section.

Frame, Transom The frame or the frame and floor plate extending athwartship across the stern post and fastened thereto. This frame acts as a foundation or support for the structure of the overhanging stern in a vessel. Frames attached to the arch and propeller post of a stern frame are also called transoms.

Frame, Transverse A frame that runs athwartship.

Frame, Web A built-up member consisting of a web plate to the edges of which single or double bars are riveted. They are placed several frame spaces apart with smaller frames in between. They extend from the tank top to the deck and between decks where extra strength is required. Where a web frame system is installed the intermediate frames may be smaller than for the ordinary framed ship. The web frame on account of its great depth is very stiff and it backs up the intermediate frames through intercostal girders running fore-and-aft between web frames.

Freeboard The distance from the waterline to the top of the Weather Deck at its side. Sometimes used with reference to the entire out of water portion of a vessel's side.

Funnel A metal chimney or passage through which the smoke and combustion gases are led from the boiler uptakes to the open air.

Funnel Cover A canvas cover used to close the top of the funnel when the fires are drawn for any length of time such as during a repair period.

Galley The space on a ship where the food is prepared; a ship's kitchen.

Galley Dresser A cook's work table in the galley. It is usually a built-in structure of metal or wood on which the cook prepares the food, having shelves and lockers fitted underneath for stowing miscellaneous cooking utensils.

Gang Board (1) Boards or a movable platform used in transferring passengers or cargo from vessel to wharf or dock or vice-versa (for this usage, also called a 'gang plank'). (2) In small boat construction, a removable deck plank.

Gang Plank See 'Gang Board'.

Gangway A place of exit from a vessel, from which passengers or crew may disembark. Gangways are fitted in the form of ports which may be closed in the sides of a vessel, and in the form of movable portions of bulwarks or railings on the Weather Decks.

General Arrangement Plans The plans showing the various quarters, spaces and compartments into which a ship is usually divided.

Generator, Electric A machine which transforms mechanical energy into electrical energy.

Generator, Engine-Driven An electric generator driven by gasoline, diesel or steam engines of the reciprocating type.

Generator, Series A direct-current generator in which the field winding is connected in series with the armature winding thus allowing the full armature current to go through the field coil.

Generator, Shunt A direct-current generator in which the field coil is shunted across the armature, thus allowing only a small portion of the armature current to pass through the field coil. The voltage of a shunt generator is very nearly constant, with a slight decrease in voltage as the load increases.

Generator, Synchronous An alternating-current generator, the speed of which bears a certain fixed relation to the frequency of the circuit.

Girder On ships this term is generally applied to continuous beams running in a fore-and-aft direction under the decks. They are used in connection with stanchions for the purpose of supporting the decks and binding the deck beams together. This term is sometimes uses to designate the longitudinals in the double bottom.

Girder, Deck A continuous beam running in a fore-and-aft direction under, and attached to, the deck beams. Also applied to a continuous range of intercostal plates and bars running fore-and-aft between deck beams. In deciding the height between decks, the depth of the girders must be considered so that sufficient head room will be provided.

Girth The distance measured on any frame line from the intersection of the Upper Deck with the side around the body of the vessel to the corresponding point on the opposite side.

Glory Hole This term has several meanings aboard ship; on *Titanic*, it was used to refer to the sleeping quarters for Stewards.

Glue, Marine A preparation of pine tar, coal tar or asphalt pitch used to fill the crevices between the planks of a wood deck to prevent water and dirt from leaking through.

Grab Line See 'Life Line'.

Grating, Wood A latticework construction of two systems of wood bars running at right angles to each other. One system is usually mortised into the other to form a flush surface. Gratings are used as drainage platforms on the Bridge, in bath rooms, in cold storage spaces, etc. They are generally made up in sections in sizes convenient for handling. Simple gratings are also often made by securing a number of small square strips of wood together with bolts or rivets, small blocks being inserted between the strips in way of the rivets to act as separators.

Gratings, Flooring, Hatchway, Walkway, Ladder Steps A structure of metal bars so arranged as to give a support or footing over an opening, while still providing spaces between the members for the passage of light and the circulation of air. For large openings gratings are usually built up in panels of comparatively small size grouped on a supporting frame. For small openings they may be made in one section of the proper size. The most common applications for gratings in marine construction are for covering fair-weather and boiler hatches, floors for oil-fired boiler rooms, walkways, and galleries in the engine and boiler rooms, ladder steps, etc.

Gratings, Hatch Gratings usually constructed of wood, fitted over hatch openings. They are particularly desirable where hatch covers are removed or opened.

Greaser A skilled, semi-skilled or non-skilled Engine Department rating, depending upon classification and assigned duties. Primarily, Greasers are those engaged in greasing or oiling any engine, machinery or shafting. Skilled ratings under the supervision of a Junior or Senior Engineer may also be engaged to start, stop and reverse the main engines or to operate other machinery within the engine and boiler rooms. Semi-skilled ratings may also be trained to do this, but only in emergencies. Skilled and semi-skilled ratings are also involved in carrying out repairs and maintenance on engines and machinery. Non-skilled ratings are engaged to carry out maintenance such as cleaning and painting within the machinery and boiler spaces, to clean the bilges, boiler smoke boxes and uptakes, and to carry out other dirty or physically arduous tasks within the purview of the Engine Department.

Gripes, Boat An arrangement for holding small boats securely in their stowage chocks. They are made up of lashings or chains fitted on one end with a turnbuckle or pelican hook and a shackle for attachment to a pad eye on the deck and on the other end with a flat bar hook for attachment to the gunwale of the boat.

Grommet A ring of fiber or some other packing material, usually soaked in red lead and used under the heads of bolts and nuts to preserve tightness. Also applied to washers or eyelets of metal.

Ground Tackle A general term for the anchor, shackle(s), and any heavy chain links attached between the anchor and its cable.

Gudgeons, Rudder Lugs cast or forged on the stern post for the purpose of hanging and hinging the rudder. They are bored to form a bearing for the rudder pintles and are usually bushed with a lignum vitae or white-metal bearing surface.

Gunwale The line where an Upper Deck stringer intersects the shell.

Gunwale Bar The bar connecting a deck stringer plate on a Weather Deck to the sheer strake.

Gunwale, Bridge The line where the Bridge Deck stringer intersects the shell.

Gunwale, Forecastle The intersection of the Forecastle Deck stringer with the shell.

Gunwale, Poop The line where the Poop Deck stringer intersects the shell.

Gunwale, Rounded The point where the shell and frames are rounded into a deck.

Gutter See 'Watercourses'.

Half-Hour Glass A sand glass that ran from one bulb to another in half an hour. It was used at sea from the Middle Ages till the mid-nineteenth century to mark the passage of each half-hour within the watch. At the end of the first half-hour, the ship's bell would be struck once, and the glass turned. At the end of the second half-hour period the bell would be struck twice, and the glass turned again. This would continue up until 'eight bells', which marked the end of the watch, except during the two 'Dog Watches', which were two hours each.

Half-Minute Glass A sand glass for timing a half minute. These were used as log timers and survived on sailing ships into the twentieth century. Their bulbs were made in one piece, unlike the two-bulb glasses made to measure longer periods.

Halyards Light lines used in hoisting signals, flags, etc. (*Alternate sp: 'halliards'*).

Hatch or Hatchway An opening in a deck through which cargo may be handled, machinery or boilers installed or removed, and access obtained to the decks and holds below.

Hatch, Booby (1) An access hatch leading from a Weather Deck to the quarters. (2) A small companionway readily removable in one piece. (3) A wooden hood-like covering for a hatch, fitted with a sliding top.

Hatch, Cargo The deck openings leading to the cargo holds.

Hatch Carlings Fore-and-aft girders running under the coamings at the sides of hatches and to which the partial or half deck beams are attached.

Hatch Cleats The clips attached to the outside of the hatch coamings for the purpose of holding the hatch battens and edges of the tarpaulin covers.

Hatch Covers Covers for closing up the top of hatchways, usually made of wood planks and in sections that can be handled by the crew. When made of wood, one or more tarpaulins are stretched over them to keep out the rain and sea. Watertight covers made of steel plates are also in use, but they are more or less in the way when the cargo is being handled.

Hawse, Anchor See 'Hawse Pipes'.

Hawse Pipes Tubes leading the anchor chain from the deck on which the windlass is located down and forward through the vessel's bow plating. Hawse pipes are generally of cast iron or cast steel. They are of heavy scantling and sometimes made in two or more parts to facilitate construction.

Head In small boat construction, the uppermost part of a stem or stern post.

Heave (1) To haul. (2) To cast or hurl, as to heave the lead, or heave a line. (3) The alternate rising and falling of a vessel in a seaway.

Heave To To cease all forward motion of the ship so that it remains stationary. Usually refers to a situation in which the ship is unexpectedly required to stop at sea for purposes of effecting repairs to her propulsion machinery, to recover a crewmen who has fallen overboard, to permit the boarding of the ship from a smaller boat, or like reasons.

Heave-round A command to start pulling in the anchor cable.

Heaver A wood bar used as a lever.

Helm A term applied to the tiller, wheel or steering gear, and also to the rudder. It indicates the control of the maneuvering or steering gear as in the terms 'port the helm' and 'starboard the helm', and the position of the rudder in the expression 'lee helm'.

Heel In small boat construction, the lowest end of a stem or stern post.

Hemp Rope A type of cordage made from the fibers of the Hemp plant. Hemp rope is very durable and extremely flexible. This makes it suitable for light hoisting through small blocks. When used for standing rigging or in any semi-permanent situation, it is normally tarred since hemp absorbs water.

Hogging A condition in which the midships portion of a ship is supported by a large sea or swell while the fore and aft portions occupy the space in between wave crests or swells, such that the mass of the ship at the bow and stern is largely unsupported. Also see 'Sagging', 'Racking' and 'Torsional Stresses'.

Hog-Piece A longitudinal timber, fastened to the top of the keel of a small boat, and being substantially wider than the keel. That part of the hog-piece extending out from the keel on either side is chamfered to provide a landing for the garboard strakes. Also called a 'keel batten'.

Hoist (1) To raise or elevate by manpower or by the employment of mechanical appliances such as cranes, derricks, shear legs, tackles, differential blocks, etc. (2) Any device employed for lifting weights. (3) A service elevator used for transporting stores and supplies between decks.

Hold An area below decks designated and constructed for the stowage of cargo.

Hollow Ended (Hollow Entry) When the extremities of the waterlines in the neighborhood of the designed load line are concave to the surrounding water, and when the sectional area curve at the ends is fine indicating relatively small displacement in these locations. A ship having such a form in her fore body is said to have a hollow entrance or hollow entry. The *Olympic*-class liners and ships of similar form were decidedly the opposite of this, being much fuller in the ends. While the *Lusitania* and *Mauretania* had a narrow, or 'fine' entry, perhaps the best example of a large liner having a hollow entry was the *Normandie.*

Holystone (1) A soft sandstone used in scrubbing wood decks. The origin of the name may be due to the kneeling posture of the men while using the stone, or else to the fact that they were formerly most frequently used on Sunday. (2) To clean a deck by the application of a holystone.

Hood Ends In small boat construction, the ends of the planks where they fit into the rabbets at the stem and stern of the boat.

Horning Setting the frames of a vessel square with respect to the keel after proper inclination to the vertical due to the declivity given the keel on the slipway in respect to dead level. See 'Plumbing'.

Horsepower (HP) The unit of power, taken as 33,000 foot-pounds of work performed in one minute, or the equivalent.

Horsepower, Brake (BHP) The actual or useful horsepower of an engine or motor measured at the output shaft, as determined by brake dynamometer testing.

Horsepower, Effective (EHP) The actual power available for propulsion which is equivalent to the indicated or shaft horsepower less all losses due to friction of machinery, line shafting, stern bearings, etc.

Horsepower, Indicated (IHP) The power actually developed by the steam acting against the piston within the cylinder or cylinders of a reciprocating engine; usually determined by use of a calibrated pressure sensing and recording device called a 'Steam Engine Indicator'. Ihp does not account for losses arising from resistance in the machinery.

Horsepower, Shaft (SHP) The horsepower obtained from a torsion meter applied to a calibrated section of the line shafting. This is the method used to measure the power output of turbines, where it is not possible to use an indicator.

Hot Well A receptacle for the water condensed from steam.

Hound The point on a mast at which the band for attaching the shrouds (termed the 'hound band') is fitted.

House Flag A flag carrying the name, symbol, and/or colors of the company to which the ship belongs.

Hull The framework of a vessel, together with all decks, deck houses, the inside and outside plating or planking, but exclusive of masts, yards, rigging and all outfit or equipment.

I-Beam A rolled shape, generally of mild steel, having a cross-section shaped like the letter 'I'. In ship work it is used for bulkhead stiffeners, girders, etc. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Ihp See 'Horsepower, Indicated'.

Inboard Towards the center; within the vessel's shell and below the Weather Decks.

Inboard Profile A plan representing a longitudinal section through the center of the vessel, showing heights of decks, locations of transverse bulkheads, assignment of various spaces and all machinery, fittings, etc., located on the center or between the center and shell on the port side.

Inclinometer A sensitive, accurate instrument with magnetic needle and graduated ring dial, for measuring the force of magnetic attraction exercised by the earth, also the direction of the attraction relative to the plane of the horizon.

Inductance The property of an electric circuit which results in an electromotive force being induced in it due to a change in the value of the current it is carrying is called its self-inductance, and the process is called self-induction. When two conductors or circuits are related such that a change of current in one results in an electro-motive force being induced in the other, they are said to have a mutual inductance and the process is called mutual induction.

Induction Coil An electrical device consisting of a primary and secondary coil on a soft iron core. The most common form of induction coil consists of a primary coil of a few turns of coarse wire wound on the core and connected to a voltaic cell through a vibrator, and a secondary coil of a large number of turns of fine wire wound upon the primary coil and carefully insulated from it.

Inner Bottom (1) The inner skin or tank top plating. (2) The plating over the double bottom.

Inner Bottom Plate A term applied to any of the plates in the tank top.

Intercostal (1) Occurring between ribs, frames, etc. Where two members of a ship intersect, the term is broadly applied to the one that is cut in way of the other. (2) A girder composed of short members running between and attached to continuous members.

Inwale See 'Clamp'.

Jack A flag flown from the bow of a ship. (Exception: the term 'Union Jack' refers specifically to the national flag of the United Kingdom.)

Jackstaff The flag pole erected at the bow of a vessel.

Jackstay A rope, wire, rod or pipe rove through eyebolts fitted to bulwark plating and other structural members, for the purpose of attaching the outer boundary rope of an awning or canvas weather screen. In some instances, the eyes through which a jackstay passes may be worked into the ends of stanchions.

Jacob's Ladder A ladder having either wire or fiber rope sides with wood or metal rungs attached at regular intervals. One end is usually fitted with sister hooks or shackles for hooking on the rail or gunwale of a ship. Typically used by pilots to board or disembark from a ship at sea.

Joggled A method of joining steel plates in which a frame or plate is offset in the way of a lapped joint. The object of the joggle is to dispense with the necessity of fitting a liner.

Joggled Frame A frame in which offsets are worked in the way of the laps of the shell plating. By joggling or offsetting the frames at a lap both plates fit snug against the frame.

Joggling Machine A machine in which two short, power-driven rolls are used for joggling, or crimping, or offsetting plates. The rolls are offset in such a way that a plate is joggled, or crimped by passing through the machine. These machines are generally operated by an electric motor.

Joiners Woodworkers who make and set up all the woodwork requiring considerable skill such as panels, doors, sashes, built-in furniture, etc.

Joinery The craft of assembling decorative woodwork in the interiors of ships and other structures. Joinery involves complex curves and detail, often with carved surfaces and with complex intersections and joints, and frequently using high-quality, highly finished varieties of woods.

Joint, Butt (1) A joint in which the connection between two pieces of material is made by bringing their ends or edges together and by fastening the same by a strip or strap that overlaps both pieces. Holes for bolts or rivets are drilled or punched in the straps and pieces to be connected. (2) The term 'butt' also refers to the end joints between plates. Originally, all end joints were butted, so the term came to be used in a general way to signify any end joint. The contradictory-sounding terms 'lapped butt' and 'butt lap' refer to an overlapping end joint.

Joint, Edge A joint formed along a fore-and-aft seam.

Joint, End A cross joint of a longitudinal part, in contradistinction to an edge joint. See 'Joint, Butt' (2).

Joint, Lapped A joint in which the connection between two pieces of material is made by overlapping the end or edge of one over the end or edge of the other and by fastening the same by bolts or rivets.

Jury Rigged Improvised; makeshift.

Jury Rudder A term applied to any temporary or makeshift appliance that is used to steer a boat when the regular rudder is out of commission.

Keel A centerline strength member running fore and aft along the bottom of a ship and often referred to as the backbone of the ship. In wood ships, it is composed of pieces of timber as long as can be obtained, which are scarfed together at their ends. In steel vessels it is composed either of long bars scarfed at their ends or by flat plates connected together by butt straps.

Keel, Bar A keel projecting below the bottom of a vessel and consisting of an iron or steel bar. The garboard strakes of shell plating are flanged down and riveted to it. These bars are obtained in as long lengths as possible and their joints are scarfed. The proper size may be obtained from the rules of the Classification Societies.

Keel, Bilge A long fin fitted on the bottom of a ship at the turn of the bilge to reduce rolling. It commonly consists of a plate running fore and aft and attached to the shell plating by angle bars. It helps materially in steadying a ship and does not add much to the resistance to propulsion.

Keel Board In small boat construction, a sturdy piece of timber longer than the keel, fastened to foundation blocks and serving to support the keel as the boat is built.

Keel, Flat Plate A plate of extra thickness riveted to the bottom angles of the keelson. By 1912, the flat plate keel had been substituted for the bar keel in most steel ships because it saved draft and was sufficient for docking purposes. Grounding on a rocky or uneven bottom was a rare occurrence, and when this did happen a bar keel was usually not strong enough to prevent disaster. Where extra strength was required the flat plate keel consisted of two plates riveted together with their butts staggered.

Keel Plate (1) A plate used to connect the wood keel to the iron or steel framing in a composite ship. (2) Any single plate composing the keel.

Keelson (1) The fore-and-aft girders in the bottom of a steel ship, whether on the centerlines, to one side or at the bilge. In wood ships, a keelson consists of a strong timber running along the top of the transverse frames parallel to and directly above the keel. (2) In small boat construction, a longitudinal strengthening member fitted in line with the keel on top of the hog-piece.

Keelson, Vertical-Center The lower middle line girder, which in conjunction with a flat plate keel on the bottom and a rider plate on top, forms the principal fore-and-aft strength member in the bottom of a ship. In addition to its importance as a 'backbone', or longitudinal strength member, it serves to distribute and equalize the pressure on the transverse frames and bottom of the ship when grounding or docking occurs. In steel ships this keelson usually consists of a vertical plate with two angles running along the top and two along the bottom. The girder, however, may be made up of various combinations of plates and shapes. This member should continue as far forward and aft as possible.

Kilowatt The practical unit of electrical power. One kilowatt equals 1,000 watts.

Knee In wooden vessels, a block of wood having a natural angular shape, or a block cut to a bracket shape and used for the purpose of fastening and strengthening corners of deck openings, intersections of timbers, and supporting deck beams. Large knees to support beams and other major structural members are normally cut from a section of a tree having a natural angle to it, for example where a large limb grows out of the trunk. This is done to ensure that the grain of the wood will follow the curve of the knee, thereby ensuring the greatest strength.

Knot (1) A unit of speed equaling one nautical mile per hour. (2) A division of the log line which serves to measure a vessel's rate of speed. (3) A connection made with a piece of cordage to another piece or to another object.

Knuckle An abrupt change in direction of the plating, frames, keel, deck or other structure of a vessel. The term is most frequently used with reference to the line at the apex of the angle dividing the upper from the lower part of the stern or counter of elliptical- or round-stern vessels.

Label Plates, Name Plates Small plates usually made of brass and embossed or engraved with the name, number, etc., of rooms, compartment, frames, valves and equipment on a vessel, and attached to or located near the article to which it refers.

Ladder A framework consisting of two parallel sides connected by bars, rungs or steps which are spaced at intervals suitable for ascending or descending. Aboard ship, the term 'ladder' is also applied to staircases used in ascending or descending from one level to another.

Ladder, Accommodation A term applied to a staircase suspended over the side of a vessel from a gangway to a point near the water, to provide an easy means of access from a tender or small boat to the deck of a vessel.

Ladder, Mast A ladder attached to a mast to provide means for going aloft.

Lagging The insulating material that is fitted on the outside of boilers, cylinder cases, piping, etc.

Lamp A term that can refer either to an incandescent bulb or to the electric light fixture which holds it.

Lamp, Arc An electric lamp in which an intensely bright light is produced by an electric arc drawn between two carbon-rod electrodes. The arc lamp is arranged to separate the electrodes automatically when the current begins to flow and to feed them toward each other as they burn away at the tip. Arc lamps are used for illuminating the decks at night for cargo handling and for providing illumination for coaling operations.

Lamp, Incandescent See 'Bulb, Incandescent'.

Lamp, Pilot A lamp mounted on or near a switchboard for giving the operator a signal when a circuit breaker opens, a fuse blows, the voltage in a circuit becomes zero, or other conditions in which a circuit has changed.

Lanyard In general, this term is used to refer to the loose end of any line attached to an object for the purpose of either near or remote control.

Lap (1) In steel plate construction, the distance that one piece is laid over another in making a lap joint. (2) In reciprocating steam engines, the distance which the valve edge on the steam side extends over the port, the piston being at mid-position.

Lapstrake Construction See 'Clinker-Built'.

Larboard See 'Port Side'.

Latitude The location of a place on Earth with reference to its distance north or south of the equator. Latitude is measured in degrees, with zero being the latitude of the equator, 90° north latitude for the North Pole and 90° south latitude for the South Pole. Latitude, in conjunction with longitude, gives the location of a specific point on Earth.

Lead An apparatus used for determining the depth of water under a vessel. It is generally made of lead with a hole for bending a strap to which a marked line is attached. On sailing vessels, the lead had a cavity at the bottom that could be 'armed' with tallow in order to pick up a sample of the bottom; the type of bottom (sand, shells, gravel, etc.) was frequently useful in conjunction with a chart to determine the vessel's location.

Lead Line A fine line marked in fathoms or feet to which the lead is attached and from which the depth of water is read off.

Length by Lloyd's Rules The length from the fore part of the stem to the after part of the stern post on the range of the Upper Deck beams, except in Awning or Shelter Deck vessels, in which cases the length is to be measured on the range of the deck beams next below the Awning or Shelter Deck.

Length on Waterline The length from the fore side of the stem to the after side of the stern post or stern counter measured at the designed waterline.

Length Over All The total length overall, i.e., the length measured from the foremost to the aftermost points of a vessel's hull.

Length, Register The length from the fore part of the outer plating or planking on the side of the stem to the after part of the main stern post of screw steamers, i.e., the one to which the rudder is attached, and to the after part of the stern post of all other vessels measured on top of the tonnage deck. For scows and barges with a square bow and stern sloping up from the bottom to the deck and with neither stem, stern post or rudder post, the register length is to be taken on the deck from the extreme point of the hull at the bow to the extreme point of the hull at the stern, i.e., the overall length of the hull is to be considered the register length of such vessels.

Lifeboat A small boat carried on davits or on one of the Upper Decks of a vessel where it can be easily lowered into the water in case of an emergency.

Life Buoy A ring made of solid cork or equivalent buoyant material having an outside diameter of not less than 30in and an inside diameter of not less than 17in. The number of buoys a vessel should carry depends on her length. They should not be permanently fastened to a vessel, but should be so placed as to be readily accessible in case of emergency. One of the buoys on each side of the vessel should have a life line attached of at least fifteen fathoms in length. Life ring buoys are also placed on wharves and along water fronts, and as on a ship they are thrown to persons in the water for the purpose of sustaining them until they can be reached. Also called a 'Life Ring'.

Life Line (1) A line attached to the outside of a lifeboat below the gunwales, hung down loosely and secured to eyes at intervals, for providing handholds to persons in the water. (2) A line attached to the wire rope spanning the lifeboat davits, used by crewmen on deck to climb down to the lifeboat after it has been lowered into the water.

Life Preserver, Life Jacket A wide belt of cork blocks or other suitable buoyant material, made to wrap around the body under the armpits, and having shoulder straps so fitted that the device may be put on like a vest. The object of a life preserver is to keep a person from sinking in case a vessel has to be abandoned.

Life Ring See 'Life Buoy'.

Lifting Hooks The pair of heavy-duty hooks, one at each end of a small boat, which bear the weight of the boat as it is hoisted or lowered. A lifting hook has a long, straight shank to extend through the breast hook(s) to the keel, attaching to the keel by means of a lifting hook keel plate which is through-bolted to the keel, with a backing plate on the underside of the keel.

Light A piece of glass fitted within a frame to provide illumination by means of natural light to an interior space.

Light, Bull's-Eye A general term for a circular light in a non-opening frame, typically set into a door.

Light Waterline The line to which a vessel submerges when she is light, i.e., without cargo, or ballast in the case of merchant vessels, and without complement, stores, fuel, ammunition, feed-water, etc., in the case of war vessels.

Light-and-Air-Space A trunk required for the admission of light and air to the engine room, machinery or other similar spaces so situated as to render the direct admission of light by other means difficult or impossible. It should be noted that an area or trunk within a ship designated as a 'light-and-air-space' was to primarily provide for ventilation and not necessarily permit the light to penetrate the full distance of the trunk, depending on the distance below decks that the trunk had to run.

Lightening Hole A hole cut out of any structural member, as in the web, where very little loss of strength will occur. These holes reduce the weight and in many cases serve as access holes. This condition is particularly true in floor plates and longitudinals in a double bottom.

Lignum Vitae An extremely hard wood, oily in nature. It is used in strips or blocks as a bearing surface for the propeller shaft in stern tubes.

Limber Boards Removable boards serving as covers for waterways or watercourses.

Limber Chain A chain used to work back and forth through the limber holes to keep the same from becoming choked.

Line (1) A general term for a rope of any size used for a specific purpose. (2) Small cords such as log line, lead line and small stuff as marline, ratline, houseline, etc.

Liner (1) A flat or tapered strip of steel or iron plate placed under a plate or other part to bring it in line with another part which it overlaps. Also used in leveling machinery foundations. (2) A passenger ship or passenger-cargo ship which transports people and freight from one destination to another along regular trans-oceanic routes according to a schedule. The term does *not* apply to ferries or other vessels engaged in short-sea trading, nor cruise ships where the voyage itself, and not point-to-point transportation, is the prime purpose of the trip.

Lines, Bevel A representation by means of lines of the inclinations which one set of surfaces make with others or with a datum line.

Lines (on a ship) (1) Chalk lines whose position may be permanently fixed by center punching. (2) Wires or cords for temporary use.

Lines (Plan or Drawing) A drawing showing a vessel's form, projected on three planes perpendicular to each other. Conceiving the surface of the vessel cut by planes parallel to each of these three reference planes, the intersections of these with the vessel's form will be curved lines which may be projected on the three reference planes. The projection of any particular intersection will appear as straight lines on two of the reference planes and as a curved line on the third.

List The deviation of a vessel from the upright position due to flooding, shifting of cargo, or other cause.

Load Line The line on the 'lines plan' of a ship representing the intersection of the ship's form with the plane of the water's surface when the vessel is floating with her designed load on board. Also applied to the actual intersection of the surface of the water with a vessel's side.

Loft, Mold A special building or floor of a building within a shipyard, constructed for the purpose of laying out the design of each ship before it is constructed. A mold loft consists of a large floor upon which the loftsmen chalked the lines of the cross-sections of a ship at full size, and the length at quarter scale.

Loftsmen Workmen who lay down the ship's lines full size on the mold loft floor and make templates or molds for the various parts or details of the vessel's structure.

Log An apparatus either for ascertaining the momentary speed of a vessel in knots or the distance traveled in a given time.

Log Line The line connecting a log-chip or harpoon log to the vessel or between the rotator and the registering mechanism of a taffrail log.

Longitude The location of a place on Earth east or west of a north–south line called the Prime Meridian, running through the Royal Naval Observatory at Greenwich, England. Longitude is given as an angular measurement ranging from 0° at the Prime Meridian to 180° east longitude, and from the Prime Meridian to 180° west longitude, lines of longitude being not parallel, but running north and south and intersecting at the poles. Latitude, in conjunction with longitude, gives the location of a specific point on Earth.

Longitudinal A general term meaning fore-and-aft, as longitudinal bulkhead, longitudinal strength, etc. A fore-and-aft girder in the bottom of a ship or a side keelson.

Longitudinal Girders The fore-and-aft girders in the bottom of a ship. These girders are usually made up from plates and shapes and are sometimes intercostal and at others continuous. Where the plates are cut at the floors, either or both, the top and bottom bars may be made continuous by notching out the floor plates in their way and cutting the floor bars. Frequently referred to as 'longitudinals'.

Louver Diagonal, overlapping slats, fitted within an opening or panel to permit the passage of air, while shutting out the view through the opening. Louvers are found in door panels, the openings in ventilation ducts, sidelight screens, and the like.

Lubber's Point A vertical mark on the inside rim of the card chamber of a compass which is held in coincidence with the point of the compass card indicating the desired course to be steered. The installation of the binnacle is such that with proper adjustment of this mark the center of the compass card and the fore-and-aft centerline of the vessel lie in a vertical plane. Also called a 'Lubber's Line'.

Mainmast In a steamship having two masts, the mast located toward the stern of the ship.

Majolica Originating from the Italian *maiolica*, used to describe earthenware covered with an opaque glaze of tin oxide and usually richly colored and decorated. On the *Olympic*-class liners, the term was used in reference to some electrical fixtures; however, there were no true Majolica fittings on these ships and the term is presumed to refer to glazed (porcelain) fixtures.

Manhole A round or oval hole cut in floors, tank tops, decks, tanks, boilers, etc., for the purpose of providing access.

Manhole Cover A cover or lid used to close a manhole opening. Manhole covers may be air-, water-, steam- or oil-tight. The simplest type consists of a plate and gasket fastened by bolts, but for easy access and tightness, a hinged cover on a raised frame is more desirable.

Maneuvering Platform See 'Starting Platform'.

Manila Rope A type of cordage made from fibers of the Abaca plant. Its strength and flexibility are comparable with hemp, and has good elasticity. However, unlike hemp, manila rope is unaffected by salt water. These factors combine to make manila more suitable than hemp for non-steel lines that must carry a load, where degradation and loss of strength cannot be risked. This also makes manila the most suitable material for hawsers (mooring lines) when synthetic materials or wire rope is not used.

Margin Plank The plank forming the boundary of the deck planking.

Margin Plate The plate forming the side of the inner bottom tank. This plate is usually fitted normal to the shell to which it is attached by a continuous angle bar and has its top edge flanged over to make a seam. The side frames are usually attached to this plate by large brackets.

Mast A long pole of steel or wood, usually circular in section, one or more of which are erected vertically on the centerline of a ship. The mast may be in one piece or it may be a series of pieces banded together to form one continuous pole. On a steamship the masts serve as supports for the rigging, cargo-handling gear and wireless antenna.

Mast Collar A piece of wood or a shape, usually an angle bar, that is formed into a ring and fitted around the mast hole in a deck.

Mast Fittings Bands, caps, pads, etc., fitted to a mast of supporting topmasts, heels of booms, etc., and to which the shrouds, blocks, etc., are secured.

Masthead The upper portion of a mast above the hounds.

Matchboard See 'Tongue-and-Groove'.

Metacenter The point of intersection between two vertical lines, one line through the center of buoyancy of the hull of a ship in equilibrium (i.e., when floating upright) and the other line through the center of buoyancy of the hull when the ship is inclined to one side. When the metacenter is above the center of gravity, the position of the vessel is stable, and when below it, the vessel is unstable.

Metacentric Height The vertical distance between the metacenter and the center of gravity of the vessel. The distance of metacenter above the center of gravity is an indication of the vessel's stability, or lack thereof.

Microfarad The practical unit of electrical capacity. It is the millionth part of the farad.

Middle Body, or Mid Body That portion of the ship adjacent to the midship section. When it has a uniform cross-section throughout its length, and its waterlines are more or less parallel to the centerline, it is called the parallel middle body.

Middle Line Sometimes used in lieu of centerline, particularly with reference to bulkheads, floors or other transverse members of the vessel.

Midship Section The vertical transverse section located at the mid-point between the forward and after perpendiculars. Usually this is the largest section of the ship in area.

Mill Scale The hard, brittle coating of several distinct layers of iron oxides formed during the processing of rolling steel plates. It is magnetic in nature (Fe_3O_4 predominantly) with an iron content ranging from 66 to 88 per cent.

Molded Breadth The ship's maximum breadth measured to the outside, or heel, of the frame bar and occurring generally, though not always, at the midship section.

Molded Depth The vertical distance from the base line to the molded line of the Main Deck at the side, measured at the midship section.

Molding, Knuckle A batten or strip of wood or steel usually cut to a half-round cross-section and used to cover the knuckle line.

Mold Loft See 'Loft, Mold'.

Mooring (1) The operation of anchoring a vessel in a harbor or securing it to a mooring buoy or to a wharf or dock by means of chains or ropes. (2) To make a vessel fast to a buoy or by anchoring. Technically, a vessel is moored when she has two anchors down at a suitable distance apart with such a length of chain on each that she is held with her bow approximately stationary on a line between them, although allowing the stern of the vessel to swing with the tide and wind.

Mooring Pipe An opening through the steel plating of the hull, specially constructed to permit a mooring line to pass through without chafing.

Moorings Heavy chains permanently anchored in a harbor to which vessels may ride. To these are attached buoys having chains of the proper length and strength to permit hauling on board through the hawse pipes.

Mortise-and-Tenon A joint formed by creating a usually rectangular cavity (the mortise) in a piece of wood or other material, prepared to receive a similarly shaped projection (the tenon) on the mating piece.

Motor, Series A direct-current or alternating-current motor in which the field coil is connected in series with the armature winding, thus allowing the armature current to flow through the series field. The high starting torque and the variable speed of the direct-current motor make it specially suitable for cranes and traction purposes.

Motor, Shunt A direct-current motor in which the field coil is shunted across the armature winding. The speed of a shunt motor is practically constant from no load to full load.

Motor, Synchronous An alternating-current motor, the speed of which bears a certain fixed relation to the frequency of the circuit independent of the load on the motor. Such a motor must be brought up to synchronous speed by external means or by a special winding before the field winding is energized.

Mould Loft See 'Loft, Mold'.

Mud Box See 'Rose Box'.

Mullion A member running parallel with the stiles on a panel door used to receive the inner edges of the panels where two or more panels are used.

Mushroom Ventilator A ventilator shaped like a mushroom, and designed so that the airflow past the ventilator will induce an area of low pressure under the hood, thereby drawing air up through the ventilator.

Natural Ventilation See 'Ventilation, Natural'.

Nautical Mile A distance approximately equal to 6,080ft, or exactly one-sixtieth of a degree on the equator.

Oakum A substance made from soft vegetable fiber such as hemp or jute, and impregnated with pine tar. It is principally used for caulking the planking on wood decks of steel vessels and for caulking all the planking on wood ships where watertightness is desired, as well as caulking around pipes.

Oar Lock A U-shaped opening cut out of the upper strake in a boat to serve as a fulcrum for an oar. Also called a 'Row Lock' *(chiefly British).*

Offsets The coordinates of a ship's form, i.e. height above the baseline and half-breadths at each section defining points of intersection at each station for the various water and buttock lines. Included are offsets for the sheer line, decks and very often, the side stringers. The rough coordinates, which are initially obtained by measurement from the lines plan, are then assembled in tabular form to produce a 'Table of Offsets', which is essentially a numerical expression of the vessel's shape in form of X, Y and Z coordinates, and may be thought of as a digitized version of the lines plan. The rough offsets obtained from the lines plan are refined and made more precise during the process of laying-off and final fairing of the ship's lines in the mold loft.

Ohm A practical unit of electrical resistance. It represents the resistance of a column of pure mercury 106.3 cm long, of uniform cross-section and weighing 14.4521 grams at 0°C.

Oil Service Tank In a lubricating-oil system, the tank from which the oil feed pipes lead in supplying the various journals, etc. In a fuel-oil system, the tank or tanks from which oil fuel is drawn direct to the burners.

On Deck (1) On the Weather Deck. (2) frequently used to imply 'on duty'.

Open Bridge House A bridge house open to the weather on each side.

Ormolu From the French *or-moulu*, signifying ground or pounded gold. Refers to a type of cast-bronze ornament, finished by hand-chasing and surfaced with gold. Also known as gilt-bronze and often used to refer to bronze furniture mounts enhanced by gilding. Broadly refers to any type of brass that looks like gold, an imitation of gold, or any of several copper and zinc or tin alloys resembling gold in appearance and used for electrical fixtures or to ornament furniture, moldings, architectural details, etc.

Outboard Profile A plan representing the longitudinal exterior of a vessel showing the starboard side of the shell, all deck erections, masts, yards, rigging, rails, etc.

Overhang That portion of a vessel's bow or stern which projects beyond a perpendicular at the waterline.

Packing, Gland Packing for use in a stuffing box and against which the gland is forced. Packing material varies in character according to its use.

Pad Eye A fitting having an eye integral with a plate or base in order to distribute the strain over a greater area and to provide ample means of securing. The pad may have either a 'worked eye' or a 'shackle eye' or more than one of either or both. The principal uses of such a fitting is that it affords means for attaching rigging, stoppers, blocks, and other movable or portable objects. Pad eyes are also known as 'lug pads', the two terms being practically synonymous. A pad eye fitted to a steel plate is often termed an 'eye plate'. Also see 'Eye'.

Painter A length of rope secured at the bow of a small boat for use in towing or for making it fast. It is sometimes termed a bow-fast.

Palm (1) The fluke, or more exactly, the flat inner face of the fluke, of an anchor. (2) A sailmaker's protector for the hand used when sewing canvas. It consists of a strong canvas or leather strap to which is secured a flat metal disc thimble to drive the needle through the canvas. (3) The flat surface at the extremity of a strut or stanchion for attachment to plating, beam or other structural member.

Panting The in and out vibrations of the frames and plating. Most noticeable in the bow and stern.

Parceled Tightly wrapping straps of canvas around a rope with the upper edges overlapped. For wire rope the strips should be coated with red lead and linseed oil and for fiber rope they should be tarred. Parceling is part of a multi-layer system of protection against deterioration and chafing in which worming, parceling and serving are all done together.

Peak, Fore or After The space at the extreme bow or stern, respectively, below the decks.

Peak Tank A tank or tank space built into or formed in the extreme forward or after lower portion of a vessel's hull.

Pelican Hook A type of quick-releasing hook used at the lower ends boat gripes, etc. A pelican hook is designed so that it can be released under tension without having to haul on the line to slack off the hook. For this reason pelican hooks are typically used for situations in which it would be impractical or impossible to 'slack off' a chain first, such as with the riding stoppers of an anchor cable. A pelican hook is normally released by striking it with a maul, not by unhooking it.

Pelorus A navigational instrument similar to a binnacle and mariner's compass but without a magnetic needle. The instrument is used for taking bearings, especially when the object to be sighted is not visible from the ship's compass. Also known as a 'dumb compass'.

Pig Iron Iron cast in the form of a rough oblong or bar.

Pilaster An ornamental column or false stanchion on a light bulkhead. It usually extends out from the bulkhead for a distance of about one-half its diameter.

Pillar A post constructed of wood or steel and used as an intermediate support for girders and deck beams. Also used as reinforcement under decks in the way of cranes and other heavy fittings, thus helping to distribute the load to the lower structural members.

Pillar, Built-up A term applied to a column that is constructed by riveting plates and shapes together.

Pillar Crane See 'Crane, Pillar'.

Pillar, Deck A pillar supporting a deck. It is usually given the name of the deck that it supports, as Upper or Main Deck Pillar.

Pillar Head The upper end of a pillar.

Pillar Heel The lower end of a pillar.

Pintle, Locking A pintle having a head turned on the bottom end to prevent the rudder from unshipping. This pintle is frequently placed at the top so that in smaller vessels, the rudder may be unshipped without dry-docking, by trimming the vessel by the bow.

Pintles The pins or bolts which hinge the rudder to the gudgeons on the stern post. These pins are cylindrical in shape in the way of the gudgeons up to the rudder lug. Through the rudder lug they are given a conical taper and above the lug a thread is cut for a nut. The taper provides a shoulder which, by tightening on the nut, firmly fixes the pintle to the rudder lug. The upper pintle sometimes has a head turned on the bottom for the purpose of preventing the rudder from moving upward and unshipping itself.

Pipe, Auxiliary Steam A steam pipe leading from the main steam line down to auxiliary engines.

Piping, Steam Piping designed to carry live steam from the boilers to the main engines and to the various steam-driven auxiliaries.

Piping System Any system of pipes such as bilge and ballast, steam and exhaust, water, sanitary, steam heating and cargo and fuel oil systems that is installed aboard a ship for conveying water, oil, steam, etc. See 'Plumber Work'.

Piping, Water Systems of piping installed aboard ship for supplying, draining and transferring fresh and salt water. The sanitary, bilge and ballast, fire, condenser circulating and feed water systems, etc., come under this heading. See 'Plumber Work'.

Pitch (1) The distance a propeller will advance during one revolution, the distance between centers of the teeth of a gear wheel, the spacing of rivets, etc. (2) The distance between the centers of the teeth of a gear wheel or rack, between the threads on a threaded fastener, the spacing of rivets, etc. (3) The residue obtained from the re-distillation of coal tar, sometimes used as a caulking material in wooden ship and boatbuilding.

Plaffonier A ceiling lamp fitted with a glass bowl or shade.

Plank, Margin or Nibbing The extreme 'out' plank of a wood deck, fitted just inboard of the waterways and sometimes notched out to revive the ends of the deck planks. Also placed around the outside of coaming of hatches, and around manhole frames where wood decks are fitted.

Planking A term applied to wood decks and to the outside planking in wood or composite ships.

Plank Landing See 'Hood Ends'.

Plate Steel of other metal rolled or cast into form such that it has in general a consistent thickness which is small relative to its length and breadth. In ship work, mild steel plates cut to proper form are used for the shell, decks and bulkheads. Plate is generally referred to by thickness only.

Plate, Apron A plate fitted in continuation of the shell plating above the forecastle sheer strake at the stem. These plates are sometimes fitted one on each side of the stem, and serve as a foundation for the bow mooring pipes.

Plate, Boss The plate fitted around the boss of a propeller post or around the curved frames in way of stern tubes. These plates usually require furnacing and are thicker than the adjoining plating.

Plate, Butt A plate used for end connections between the ends of planking on a composite ship.

Plate, Doubling An extra plate fitted over the regular plating, either for extra strength or to compensate for an opening in the structure.

Plate, Flanged A plate in which one or more edges of are bent over to more or less of an angle. The term also applies where an aperture is made in a plate with its edges stiffened by bending them at right angles to the plate.

Plate, Furnaced A plate that requires heating in order to mold it into shape. The most common types are the oxter and boss plates.

Plate, Oxter The plate that is riveted to the stern from immediately below or on the transom. On account of the shape of the ship at this point it usually requires furnacing and molding into shape. The oxter plate is given extra thickness to compensate for the stretching and heating necessary in bringing it to shape.

Plate-Scarfing Machine A machine for scarfing or tapering the corner of a plate. The corners of shell plates are often scarfed where a seam crosses a butt lap to reduce the thickness of metal that the rivets penetrate and make a better job for water-tightness.

Plate, Sheer Strake A plate forming part of a sheer strake.

Plate, Stealer A plate taking the end of a drop strake, or a plate combining two strakes into one. Stealer plates occur at the bow and stern, where the narrowing girth compels a reduction in the number of strakes.

Plate, Web A wide girder plate as in a web frame or hatch beam. Angle bars are usually fitted on each edge.

Plating, Clinker System Where the edges of outside plating form lap joints so that one edge of a plate is inside while the other is outside. In this case tapered frame liners are generally used.

Plating, Flush System Where the edges of the outside plating form butt joints so that a flush surface is formed. The connections between plates are made by seam straps and butt straps.

Plating, In-and-Out System Where the edges of the outside plating form lap joints so that both edges of the plates are alternately inside and outside. In order to do this, the frames have to be joggled in the way of the outside strakes or frame liners of the thickness of the plating have to be fitted between the frames and outside strakes.

Plating, Rounded Gunwale Plates bent to fit a rounded gunwale and connecting the side and deck plating.

Plating, Shell The plating forming the outer skin of a vessel, exclusive of decks and superstructure. In addition to forming a watertight envelope over the frames, it contributes largely to the strength of the vessel.

Plating, Tank Top The plating forming the top of the double bottom. It is fitted to the tops of the floor plates, longitudinals and center keelson, and makes a complete inner skin extending over the bottom and sometimes up the sides of a vessel.

Plimsoll Mark A mark stenciled in and painted on the side of a vessel designating the maximum depth to which the ship may be safely loaded in various waters and times of the year. Named for Samuel Plimsoll, a member of Parliament, whose efforts led to the incorporation in the Merchant Shipping Act of a requirement that vessels be so marked.

Plumb To make straight up and down, using a weight and string, a bevel, a spirit level, or a combination square provided with a bubble glass in its stock or head.

Plumber Work A general colloquial reference to any part of the various sanitary, bilge and ballast, fire, condenser circulating and feed-water systems.

Plumbing With regard to framing, the process during erection of setting the frames plumb in respect to the line of the keel, which has been set up on the slipway with some amount of declivity to facilitate launching of the completed hull.

Plummer Blocks The blocks containing the bearings which support the line shafting and the inboard end of the tail shaft.

Poop Sheer Strake The strake of outside plating adjacent to the Poop Deck.

Port An opening in the plating or planking of a vessel for the purpose of providing access for passengers, loading and discharging cargo, taking on coal, discharging ashes and water, etc.

Portable Designed to be removable. Typically refers to railings, bulkheads, etc. that are normally in place semi-permanently, but designed to be taken out or moved out of the way when necessary. Does not normally refer to carrying them from place to place.

Porthole An opening in the side or deck house of a vessel, usually round in shape, and fitted with a hinged frame in which a thick glass light is secured. The purpose of the porthole is to provide light and ventilation to the interior. Sometimes, though infrequently, referred to as an 'air port'.

Port, Bulwark, Clearing or Freeing See 'Port, Wash'.

Port, Wash A rectangular or oval opening in a bulwark just above the deck. These ports are necessary when seas break over the deck so that the ship can clear itself quickly of these large volumes of water. As these openings are about the size of a manhole, rods or bars are generally fitted across them. Flap doors are sometimes fitted on the outside hinging outboard.

Port, Cargo An opening in the side plating or planking provided with a watertight cover or door and used for loading and unloading cargo.

Port, Coaling An opening in the side of a vessel provided with a watertight cover used for loading coal aboard a vessel.

Port, Gangway An opening in the side plating, planking or bulwark for the purposes of providing access through which people may board or leave the ship or through which cargo may be handled.

Port, Hawser An opening in the bulwark through which a hawser may be passed.

Port Side That side of a vessel to the left when looking from the stern toward the bow. In the early 1800s, the term 'port' replaced the earlier term 'larboard'.

Port the Helm A term originally applied to the operation of putting the tiller over to the left or port side, causing the rudder and ship to turn to the right or starboard. The operation of turning a steering wheel to port may cause the vessel to turn to either the right or left according to whether the leads are open or crossed or otherwise mechanically arranged. Different localities and countries and also different branches of the marine in the same locality have their own rules as to whether the ship turns with or against the wheel. Thus an order to port the helm on a vessel plying the inland waters or harbors or on the ship of a foreign country might be interpreted in the opposite direction from the same orders issued on board some deep sea and naval vessels.

Propeller A propulsive device consisting of a boss or hub carrying radial blades, from two to four (or more) in number, the rear or driving faces of which form portions of an approximately helical surface, the axis of which is the centerline of the propeller shaft. The propeller is ordinarily located at the after end of the propeller shaft. The rotary motion imparted to this shaft by the engine turns the propeller, thereby exerting a rearward thrust upon the water which reacts to force the ship ahead. The selection of proper characteristics such as diameter, revolutions, pitch, etc., the accurate determination of blade thickness, shape, etc. and the great care in construction and finish are essential to the securing of the best results from the propeller in service.

Propeller Blade, Back of The forward side of the propeller blade.

Propeller Blade Rake The sloping aft from a position at right angles on the axis of propeller shaft of the propeller blades.

Propeller Blades, Screw The radial arms, attached to the propeller hub, the faces of which form portions of an approximately helical surface the axis of which coincides with that of the propeller shaft. Blades are either cast in one piece with the hub or cast separately and designed to be attached to the hub with bolts. In this latter case provision is usually made for a slight adjustment in pitch by means of the shape of the bolt holes.

Propeller Boss The central portion of the screw propeller which carries the blades and forms the medium of attachment to the propeller shaft. It is taper-bored for the reception of the propeller shaft and slotted for a key. When properly placed upon the shaft it is forced home and secured in its final position by means of the propeller lock nut.

Propeller Cavitation That condition of screw performance in which increase of torque fails to produce a corresponding or reasonable increase in thrust.

Propeller Diameter The diameter of the circle tangent to the tips of the propeller blades.

Propeller Driving Face, or Face The after face of the propeller blade; that face which acts directly upon the water when driving the vessel ahead.

Propeller Leading Edge The forward edge of a propeller blade.

Propeller Pitch, Nominal The distance, measured parallel to the axis of rotation, between similar positions of a point of the driving face of a propeller blade in successive revolutions. When the driving face of a propeller blade lies entirely in a true helical surface the blade is said to have uniform pitch. When the pitch at the following edge is greater than that at the leading edge, the blade is said to have axially increasing pitch. When the pitch near the tip is greater than that near the hub the blade is said to have radially increasing pitch.

Propeller Pitch, Virtual The pitch of a theoretically perfect blade of no thickness which would act as does the actual blade. The pitch of the back of a propeller blade varies greatly from that of the face of the blade. Inasmuch as the back exercises a material influence upon propeller performance, correct conclusions are impossible unless proper allowance is made therefore. The virtual pitch as above defined meets this requirement.

Propeller Post The forward post of a stern frame on vessels having a centerline propeller. It provides a support for the stern tube and propeller shaft as well as a joining frame for the converging sides of the ship at the stern.

Propeller Racing The sudden increase in the number of revolutions made by the engine when the propellers are lifted clear of the water, or nearly so, due to the roll or pitch of the ship.

Propeller Shaft, or Tail Shaft That length of shafting in a screw steamship which carries the propeller. It is the aftermost piece of shafting and at its outermost end is tapered, slotted and threaded for the attachment and proper securing of the propeller itself. This piece of shafting is carried directly by the propeller strut or stern bearing and is made slightly larger than the line shafting as a precaution against corrosion and shock. It is generally encased in a brass sleeve to provide proper bearing surface and to protect the shaft from corrosion.

Propeller Slip Angle The angle between the plane of the blade face and its direction of motion.

Propeller Slip, Apparent The ratio of propeller speed to the speed of the ship.

Propeller Slip or Slip Ratio; Apparent True Slip The ratio of speed of slip to speed of propeller.

PSIG Pounds per square inch gauge; the unit of pressure measurement when the zero reference is the barometric pressure at sea level.

PSIA Pounds per square inch absolute; the unit of pressure measurement when the zero reference is a full vacuum.

Pump A machine actuated by hand or power for raising and transferring fluids or gases and for inducing a vacuum.

Pump, Air The main air pump is for the purpose of reducing the back pressure in the low pressure cylinders or turbines and also for removing the condensed steam and vapor from the condenser. These pumps are driven either by a connection with a cross-head (usually the low pressure) on the main engine or by an independent engine. They are also made single- and double-acting. The single-acting, direct-driven type is the most common. As the vacuum in the condenser with the above-described pump is dependent on the temperature of the hot well, and as water will absorb only about $^1/_{20}$ of its volume of air, dry vacuum pumps, augmenters, rotary and air ejector systems are installed where a high vacuum is desired.

Pump, Air and Circulating, Auxiliary This pump is composed of three cylinders: a steam cylinder for power, a water cylinder for circulating water through the auxiliary condenser, and a water cylinder for extracting the condensed steam in the auxiliary condenser and delivering it to the feed tank. This pump is an extravagant user of steam.

Pump, Auxiliary Circulating A pump to force water through the tubes of the auxiliary condenser. It is often combined with the auxiliary air pump. These pumps deliver to the main feed line only.

Pump, Auxiliary Feed A pump with the following suctions: from the main feed tank, the reserve feed tank, the sea, the bilge, and from the bottom of the condenser. It can deliver to the boilers, the reserve feed tank or overboard. On account of the number of leads to and from this pump, great care should be taken that fresh water is not pumped overboard, salt or bilge water pumped into the boilers (unless it is an emergency and so intended), or that the pump is used at all for boiler feed after pumping the bilge unless it has been thoroughly washed by a salt-water circulation.

Pump, Ballast A pump used for filling and emptying the ballast tanks. It has bypasses so that it can work the bilges and fire system either alone or in conjunction with the other pumps.

Pump, Bilge A pump used aboard ship to remove accumulations of water in the vessel's bottom tanks, holds and other compartments and discharge it overboard.

Pump, Direct-Acting A pump in which the piston and plunger are on the same rod, but that does not require a flywheel to carry it over the dead points.

Pump, Distiller A pump used for transferring the distillate to the culinary and supply tanks.

Pump, Distiller Circulating A pump for forcing circulating water through the distiller tubes to condense the vapor into water. It should have a bypass to the flushing system.

Pump, Donkey A pump having the same suction and discharge leads as the bilge pump, and, in addition, usually connected to the donkey boiler. Thus it can work when the main boilers are cold.

Pump, Double-Acting A pump that delivers on each stroke and from both ends of the cylinder.

Pump, Downtown A hand pump that is also a force pump. It is worked by cranks on each side of the pump chamber or, if placed on a lower deck, the cranks may work through shafting gears. It is arranged to draw from all compartments and from the sea, and discharges overboard and to the fire main.

Pump, Duplex A pair of pumps so placed that the piston rod of one pump actuates the valve.

Pump, Evaporator Feed A pump that supplies the evaporator with salt water for vaporization.

Pump, Fire and Bilge A pump used for keeping the bilges free of water, washing decks and for putting out fires. It has a sea suction and an overboard delivery of its own. It is more or less constantly in operation, keeping the bilges free of water and when used for washing decks should be cleaned by pumping salt water overboard. This pump has a suction to the bilge, drains, and inner bottom.

Pump, Fresh-Water A pump that moves fresh water from the culinary or supply tanks to a gravity tank called the 'daily supply tank'. The gravity tank feeds the fresh water supply lines to the quarters, galleys, pantries, lavatories, etc.

Pump, Lubricating Oil In a forced-lubrication system, a pump that forces lubricating oil to the shaft and engine bearings and crossheads. In a gravity-feed lubrication system, a pump that returns lubricating oil collected from the bearings to the supply tanks.

Pump, Main Circulating A pump that takes water in large quantities from the sea, forces it through the main condenser tubes and then discharges it overboard. On account of the low head to be overcome and the large capacity required, it is usually of the centrifugal type. In addition to a suction line, sea injection valve, delivery line, and overboard discharge valve, it has a bypass to the bilge which may at any time be used in pumping water overboard either directly or through the condenser. As a centrifugal pump will handle ashes and such refuse as are liable to collect in the bottom of a ship, it becomes of great value when a large quantity of water is admitted to the ship through the hatches or by accident.

Pump, Main Feed A pump that keeps the water at the proper level in the boilers. It takes fresh water either from the main or reserve feed tanks. Some types are driven from a connection to the main engine and others have independent engines. The number and location of these pumps depends on the size of the ship and the design.

Pump, Sanitary A pump that supplies salt water to the flushing system and for baths. It may deliver directly, but commonly discharges into a gravity tank, the overflow of which is carried to the water closets and troughs. It also supplies a tank in which a steam coil is installed for the purpose of providing for hot sea water baths.

Pump, Single-Acting A pump that delivers from one end of the cylinder only and on alternate strokes.

Pump, Water Service A pump for circulating cooling water through shaft bearings, crosshead, slides, etc. The delivery should also bypass to the fire main and to the distiller.

Quadrant (1) A casting, forging or built-up frame in the shape of a sector of a circle attached to the rudder stock and through which the steering gear leads turn the rudder. The hub of the quadrant is bored and keyed to fit the rudder stock. It may be in two pieces clamped together by bolts or in one piece, in which case it must be slipped down over the end of the stock. The rim of the quadrant is provided either with two grooves to take the steering chains or ropes, or in larger vessels, with gear teeth arranged to mesh directly with the pinion of the steering engine. (2) A reflecting hand-navigating instrument, constructed on the same principle as the sextant, but with a shorter limb, measuring angles up to 90° only. (3) A part of the reversing gear on a reciprocating marine engine. One quarter of a circle or its circumference.

Quarter (1) The upper part of a vessel's sides near the stern. (2) The areas of a vessel's sides about midway between the stem and the middle and between the middle and the stern.

Quarters (1) Living spaces for passengers or crew. (2) Individual stations for the crew for fire or boat drill, etc.

Quartermaster A petty officer who steers the ship and has charge of the navigating instruments.

Quay An artificial wall or bank usually of stone, made toward the sea at the side of a harbor or river for convenience in loading and unloading vessels. Pronounced 'key'.

Rabbet (1) In small boat construction, a groove in the stem, keel or stern frame into which the edges of planking or plating are fitted. (2) In small boat construction, a cleanly shaped, angular notch let into the side of the keel timber to accept the edge of the garboard strake. The rabbet is continued up the bow timbers, and in the case of a double-ended boat such as a lifeboat, it is also continued up the stern timbers to accept the ends of the strakes. (3) In joinery, a groove or channel cut in a piece of woodwork to accept another piece or panel, into which it is tightly and permanently fitted. *(Alternate sp: rebate.)*

Racking The distortion of a ship's structure in response to the transverse impact of, and/or to rolling in, very heavy beam seas, during which the sides are forced away from being perpendicular with the decks and bottom.

Rail Channel bars, shapes or flat pieces of wood fitted at the top of bulwark plating or at the top of rail stanchions. Also applied to the tiers of guard rods running between the top rail and the deck.

Rail, Hand A rail fitted along the side of a ladder or a companionway.

Rail, Main The top rail running along the top of the bulwark or rail stanchions on the upper or Weather Deck.

Rail, Poop The rail around the top of the bulwark or rail stanchions on the Poop Deck.

Rail Stanchions Steel or wood stanchions that serve as vertical posts for the guard railings or ropes enclosing an open deck, Bridge, etc. of a vessel. They are spaced at approximately equal distances and are permanently fitted or removable as the requirements dictate.

Ratlines Either short lengths of three-stranded line or rigid bars, secured to the shrouds parallel to the waterline. These serve the purpose of ladder rungs for the crew in ascending or descending to or from the upper part of the mast.

Rebate See 'Rabbet'.

Reflector, Cargo A reflector for electric lights suitable for illuminating cargo holds.

Releasing Gear Gear composed of specially constructed hooks attached to the davit heads and rods, chains or fittings installed in lifeboats. By the use of this gear both ends of a lifeboat may be released quickly and simultaneously once the boat has reached the water.

Reeve To run a line through the sheave of a block in preparation for its use.

Reverberatory Furnace A furnace in which the material inserted is heated indirectly by a flame deflected downward from the roof, rather than from below.

Reverse Frame See 'Frame, Reverse'.

Ribs Referring to the transverse frames of a boat or ship.

Ridge Spar See 'Spar, Ridge'.

Rigging A term referring, cumulatively, to all the lines used for the structural support of the ship's parts and for the operation of the ship. See also 'Standing Rigging' and 'Running Rigging'.

Rigging Screw A device for connecting two parts of a bar, rod or rope together with an adjustable tension. It consists of an internally threaded link turning on screws at each end threaded in opposite directions, or one end may have a swivel and the other, a screw. The link is operated by means of a wrench or a lever. Frequently the link is constructed with a hole through the center for applying a marline spike as a lever.

Rising In small boat construction, the upper stringer running fore-and-aft from the stem post apron to the stern post apron, and on which the ends of the thwarts rested.

Rivet A pin used for connecting two or more pieces of material by the means of passing it through a hole drilled or punched for the purpose and hammering down one or both ends. Rivets should be made from high-grade iron or mild steel, except that in cases where high-tensile steel parts are to be connected high-tensile steel rivets are generally used. Copper rivets are used for various minor purposes. In the shell plating, decking, bulkheads and the framing of a ship, as well as in the boilers, the joints must be very firm and in most cases watertight; therefore, for this reason, and because of the fact that rivets ⅜ in diameter or over can be more efficiently worked while hot, it is the practice to heat rivets before passing them through the holes and to hammer the points down before the rivet cools. The contraction of the rivet due to cooling will aid materially in producing the firm joint desired.

Rivet Counter (1) In ship construction, the men who count rivets installed by rivet gangs being paid on a piecework basis for the purpose of determining their wages. (2) A nickname for a person so engrossed in the details of a particular ocean liner or vessel that he researches the structure of his subject down to the most minute details; often used derogatorily by those who do not share the same passion. In some cases, so-called Rivet Counters are thought, even by friends and family, to have a compulsive disorder.

Rivet Spacing A term applied to the distance between the centers in a row of rivets; most commonly referred to as the 'pitch'.

Riveter, Hydraulic Usually a large, C-shaped cast-steel frame with a hydraulic ram fitted at the open end which carries the rivet set.

Riveters Workmen who drive rivets by hammering the points into the required shape either by means of hand or power tools. Riveters usually work in gangs, a gang including one or two riveters, a holder-on, a heater, and perhaps one or more passers. Riveters should be responsible for the fairness of the surfaces riveted and should see that there are no lateral bends, bumps or irregularities in the plating, because when once riveted the structure is permanent. They should also see that the surfaces are rigidly and firmly united when they perform the operation of swaging down the points of the rivets.

Riveting The art of fastening two pieces of material together by rivets.

Riveting, Bull The process of driving rivets by power machines, usually air or hydraulic.

Riveting, Chain A term applied to two or more rows of rivets that have their centers opposite each other. A line drawn perpendicular to the edge of the plate through the center of a rivet in one row will also pass through the centers of the corresponding rivets in the other rows.

Riveting, Double A connection made with two rows of rivets. In butt joints there are two rows in each piece connected.

Riveting, Hydraulic A term applied where the rivets are driven by a machine actuated by hydraulic pressure.

Riveting Machine (1) A machine designed for upsetting and forming rivet points. (2) To rivet by means of a riveting machine.

Riveting, Reeled See 'Riveting, Staggered'.

Riveting, Single A connection made with one row of rivets. In single-riveted butt joints there is one row in each piece connected.

Riveting, Staggered A connection made with two or more rows of rivets where the centers of the rivets in one row are one-half the pitch or spacing ahead of the other row. Also called 'zigzag riveting'.

Riveting, Three-ply A connection in which three thicknesses of material are connected by one rivet.

Riveting, Treble A connection is made with three rows of rivets. In treble-riveted butt joints there are three rows in each piece connected.

Riveting, Zigzag See 'Riveting, Staggered'.

Rivets, Row of A continuous line of rivets, whether vertical, diagonal or horizontal. The spacing of the rivets from center to center depends upon the nature of the connection.

Rope The product resulting from twisting a fibrous material, such as manila, hemp, flax, cotton, coir, etc., into yarns or threads, which in turn are twisted into strands and several of these laid up together. Fiber rope is designated as to size by its circumference. Wire rope is made of iron, steel, or bronze wires twisted together like yarns to form strands, which in turn are laid up to form a rope. Wire rope is designated as to size both by its diameter and its circumference.

Rope, Cable-Laid A term that was formerly exclusively applied to a rope consisting of nine strands, being made by laying three plain ropes together left-handed; but now used to denote three, sometimes four, plain laid three-stranded ropes twisted together in the opposite direction to the twists in the several ropes. Also known as 'hawser-laid' and 'water-laid' rope.

Rope Core When a fiber rope has a core it consists of a small pliable rope whose diameter is about one-third that of the strands. In a wire rope the core may consist of a tarred hemp rope where pliability is the chief consideration and a wire core where strength is more important.

Rope, Hawser A general term for heavy lines used for warping, towing and mooring.

Rope, Hemp A rope made from fibers of the Hemp plant. In manila rope the fibers are made into yarn, the yarn into strands, and three or more strands twisted up to form a rope. Hemp rope is used principally for standing rigging in sailing vessels, and when so used is normally tarred as it decays rapidly otherwise.

Rope, Iron Wire A rope made of iron wires. It has less strength but is more pliable than steel wire rope of the same make-up.

Rope Lay The direction in which it is twisted up.

Rope, Left-Laid Rope in which the strands are twisted together in the same direction as the motion of the hands of a clock.

Rope, Plain-Laid A term that was formerly exclusively applied to the three-stranded right-handed rope, but is now applied commercially to three-, four- or six-stranded rope laid up in the contrary direction to the twist in the strands.

Rope, Ridge A rope running through the eyes at the heads of the awning stanchions to which the edge of an awning is hauled out and stopped. The term is sometimes applied to the center rope of an awning.

Rope, Right-Laid Rope in which the strands are twisted together in the opposite direction to the motion of the hands of a clock.

Rope, Steel Wire A rope made from steel wires. It is used for both standing and running rigging and is normally galvanized; the latter being abbreviated 'GSWR' on rigging plans. The type used for running rigging is normally 'flexible steel wire rope', with finer strands and a hemp core. This type is also normally galvanized, and abbreviated 'FSWR' on rigging plans.

Rope, Wire See 'Rope, Steel Wire'.

Rope Yarn This consists of fibers of manila or hemp which are usually twisted up in a right-handed direction.

Rose Box The enlarged terminal on the suction end of a pipe and forming a strainer which prevents the entrance of material liable to choke the pipe. Also called a 'mud box' or a 'strum box'.

Roses (1) Perforated metal plates, fitted over the outside of injection sea cocks in order to prevent the entrance of weeds or other foreign substances to the ship's piping system or pumps. (2) A perforated nozzle for delivering water in a fine jet.

Round of Beam See 'Camber'.

Row Lock See 'Oar Lock'.

Rubber See 'Rubbing Plank'.

Rubbing Plank In small boat construction, a sacrificial (replaceable) plank fastened to the outside of the hull to prevent damage to the hull from chafing against pilings, the hull of a ship, etc.

Rubbing Strake See 'Rubbing Plank'.

Rubbing Strip (1) A plate riveted to the bottom of a keel to afford protection in docking and grounding. (2) An alternate term for a rubbing plank.

Rubstrake See 'Rubbing Plank'.

Rudder A device used in steering or maneuvering a vessel. The most common type consists of a flat slab of metal or wood, hinged at the forward end to the stern or rudder post and rounded at the after end to make a fair ending to the lines of the vessel. When made of metal it may either be built up from plates, shapes and castings, with or without wood filling, or it may be a casting. The rudder is attached to a vertical shaft called the rudder stock, by which it is actuated or turned.

Rudder, Balanced A rudder having the forward or leading edge of the whole or a portion of the rudder far enough forward of the centerline of the rudder stock to bring the center of pressure of the water on the rudder at the maximum helm angle on or near the centerline of the rudder stock.

Rudder Frame The framework of a rudder, formed from a vertical or main piece and the arms that project from it.

Rudder Head The upper end of the main piece to which the rudder stock is attached. The head consists of a flange or thick palm to which a flange or palm on the lower end of the rudder stock is bolted.

Rudder Heel The lowermost portion of the main piece of a rudder.

Rudder Post See 'Stern Post'.

Rudder Stock A vertical shaft having a rudder attached to its lower end and having a yoke, quadrant or tiller fitted to its upper portion by which it may be turned. In addition to the function of turning, where practical, the stock should take the weight of the rudder through a carrier attached to the stock which works on a bearing fitted at the top of the rudder trunk or on a platform or deck.

Rudder Stops Fittings attached to the structure of the ship or to shoulders on the stern post which have the function of limiting the swing of the rudder to an angle of about 35 or 40°.

Rudder Trunk The well in the stern or beneath the counter which holds the rudder stock.

Runner (1) A length of rope made fast at one end and rove through a single movable block. (2) (*Ship joinery*) Also called a 'Lintel'; the overhead attaching member of a wood partition or bulkhead, fastened to the underside of the deck beams above a corresponding cant. See 'Cant' (3).

Running Rigging Lines that are not fixed in place, but which run through blocks or pulleys for purposes of applying a pulling force. Running rigging is used to raise and lower cargo, hoist signal flags, and for similar purposes. Some running rigging was left in place all the time (example – signal halyards), while some running rigging was set up only when needed (example – lines for hoisting cargo).

Sagging A condition in which the bow and stern areas of a ship are supported by large seas or swells while the midship portion occupies the space in between wave crests or swells, such that the mass of the ship amidships is largely unsupported. Also see 'Hogging', 'Racking' and 'Torsional Stresses'.

Sand Glass This device for measuring intervals of time has two pear-shaped glass bulbs, one above the other, joined together at their pointed ends or necks by a narrow tube, through which fine sand or marble powder slowly runs down in a pre-determined space of time. See 'Half-Hour Glass'; 'Half-Minute Glass'.

Sanitary Fixtures Plumbing appliances and fittings such as toilets, bath tubs, showers, lavatories, toilet cases, waste jars, supply pitchers, carafe, water heaters, etc.

Sanitary System A system of piping supplying and draining the plumbing fixtures aboard a ship such as lavatories, showers, toilets, sinks, etc. See 'Plumber Work'.

Sanitary Tank See 'Tank, Sanitary'.

Sash, Window A frame for holding the glass. It is generally composed of a horizontal piece at the top, called the top rail; a horizontal piece at the bottom, called the bottom rail; or, where beveled in an upper sash, a check rail, the sides called stiles, and pieces dividing the sash into separate lights called mullions or bars.

Scantlings A term applied to the dimensions of the frames, girders, plating, etc., that go into a ship's structure. The various classification societies publish rules from which these dimensions may be obtained and, as these rules are the results of continued observation of ships' structures, they give the most reliable information from a practical standpoint that can be obtained. The forces acting on a ship at sea cannot be accurately determined, hence calculations made to determine the size of a member of a ship's structure should be compared with similar calculations on existing practice where possible.

Scarf A connection made between two pieces by tapering their ends so that they will mortise together in a joint of the same breadth and depth as the pieces connected. It is used on keels, stem and stern frames, etc. Also used to designate the tapering, planing away or notching of the corner of a plate where a joint occurs. *(Alt. spelling: scarph)*

Scarph See 'Scarf'.

Schooner A sailing vessel with two or more masts rigged fore and aft.

Sconce A metal bracket, sometimes with a reflector behind it, attached to a beam or bulkhead to hold a candle or lamp.

Scrive Board A portable platform made of soft, clear, planed lumber on which a full-sized body plan of a ship is drawn, the lines being cut into the surface of the wood in small U-shaped grooves by means of a scriving knife, to prevent them from being obliterated.

Scupper Holes Drain holes cut through the gunwale of deck stringer angle bar and adjoining shell plate to allow water to drain directly from the gutter or waterway overboard. Where strength considerations prevent the holes being cut in angle bar plating, a scupper pipe is fitted, leading down through the deck and to a fitting in the ship's side.

Scupper Pipes The pipes leading from the scupper to the fitting in the ship's side, for carrying accumulations of water from the deck overboard.

Scuppers Drains from decks to carry off accumulations of rain water or sea water. The scuppers are placed in the gutters or waterways on open decks and in corners of enclosed decks, and connect to pipes leading overboard. The flap valve at the bottom of the scupper pipe is also often called a scupper.

Scuttle (1) A small opening, usually circular in shape, and generally fitted in decks to provide access as a manhole or for stowing fuel, water and small stores. A cover or lid is fitted so that the scuttle may be closed when not in use. (2) To open a sea valve or otherwise allowing the sea to enter a ship for the purpose of sinking her.

Sea Cock A cock or valve close to the vessel's side, for closing a pipe which communicates with the sea.

Seas The swell of the ocean or other body of water as a result of a sustained wind blowing over the surface of the water for an extended period of time; the motion of the water's surface. With regard to the effect on a ship, often referred to by the direction from which the seas approach the vessel, as in a 'beam sea', in which the seas are coming from abeam.

Section A drawing showing the internal arrangement of a ship as it would appear if cut by a plane, usually longitudinally or transversely.

Seizing Securing two ropes or two parts of the same rope together by tightly binding them with seizing stuff. Seizings are named according to their location and use, as throat or eye seizings, round seizing, flat seizing, etc. Several different ways of passing the seizings and making the finish are in general use for each of the above kinds.

Seizing Stuff A tarred, right-handed, three-stranded small stuff of two, three or four threads to the strand, usually of hemp. It is heavier and stronger than house-line or round-line, being made by machinery and finished similar to the larger sized ropes. Seizing stuff is also made in galvanized annealed steel wire, six wires around a wire center, varying from $^{1}/_{16}$in to ¼in diameter.

Served A means of protecting a line by applying a tightly wound layer of twine around a line. Serving is part of a multi-layer system of protection against deterioration and chafing in which worming, parceling and serving are all done together.

Sextant A hand-navigating instrument for measuring, by reflection, the angle subtended at the eye by two distant objects by a single observation. It is the most convenient and accurate instrument yet devised for use where the observer has a very unstable support, as on board ship, and is very generally used by navigators and surveyors for determining the attitude of celestial bodies and the angular distance between them as well as the horizontal angular distance between terrestrial objects. The name is derived from the fact that the limb of the instrument includes but an arc of 60° of a circle, but owing to double reflection, angles up to 120° may be measured with it. The scale is graduated to 120° in a length of 60°. A different form of instrument, known as the prismatic sextant, measures angles up to 180°.

Shackle A U-shaped link whose end is closed by a removable pin or bolt. Shackles are used principally to connect the shots of chain cables, blocks to davit heads, and rigging to mast bands and deck connections, etc.

Shaft Alley See 'Shaft Tunnel'.

Shaft Angle The angle which a propeller shaft makes with the line of intersection between the designed water plane and the longitudinal center plane of the ship. In many cases the horizontal shaft angle is ignored and only the angle which the shaft makes with the designed water plane is considered. This may be slightly less than the true shaft angle.

Shafting, Line or Intermediate The length of shafting located between the thrust shaft and tail shaft.

Shaft Stools The seatings upon which the plummer blocks and line shafting are supported. In addition to supporting the weight of the shafting they have to resist any side-bending tendency due to vibrations or torsional loading of the shaft.

Shaft Tunnel A watertight passage housing the line shafting from the machinery spaces to the bulkhead at which the stern tube commences. It provides access to the shafting and its bearings and also prevents any damage to the same from the cargo in the spaces through which it passes. Also called a 'shaft alley'.

Shafting Cylindrical rod or tubing used, in general, for the transmission of rotary motion from the source of power to the machine or device being driven.

Shape Any of the long bars of constant cross-section such as angle bar, bulb angle bar, tee-bar, bulb tee, channel, etc.

Sheave A metal disc having a groove around its cylindrical surface to allow a rope or chain to run over it without slipping off. Pronounced 'shiv'.

Sheer The longitudinal curve of a vessel's rails, deck, etc., the usual reference being to the ship's side; however, in the case of a deck having a camber, its centerline may also have a sheer. The amount by which the height of the Weather Deck at the after or forward perpendicular exceeds that at the mid perpendicular. Mean sheer is the average of the sheers forward and aft as just defined.

Sheer Line The longitudinal curve of the rail or decks, which shows the variation in height above water or freeboard, throughout the vessel's entire length.

Sheer Strake The strake of shell plating that runs along the level of the Main or Upper Decks. Plates running along the level of lower decks are not called sheer strakes. Sheer strakes, on account of their distance from the neutral axis of the ship, are important strength members, and when adjacent to a strength deck they are made thicker than the side plating.

Shell Doublings Extra plates fitted over the portions of the shell plating requiring additional strength. Also fitted as compensating plates in the way of ports or apertures.

Shell Landings Those portions of the edges of shell plating occupied by the laps.

Shelter Deck Sheer Strake The strake of outside plating adjacent to the Shelter Deck.

Shifting Beam A portable beam fitted in a hatchway for the purpose of supporting the hatch covers. The ends of the beams are fitted in slotted carriers attached to the inside of the hatchway coamings.

Ship (1) A large vessel that carries passengers or freight. (2) To transport by such a vessel. (3) To place or fit something in its designed place of mounting. (4) To take aboard; in this context frequently used to refer to large quantities of water inundating the Weather Decks. Also see 'Boarding'.

Shoot See 'Chute'.

Shot A 15-fathom length of chain anchor cable.

Shoveling Boards Boards placed in the bottom of coal bunkers to form a level surface.

Shp See 'Horsepower, Shaft'.

Shroud (1) A hemp or wire rope which supports a mast in a lateral direction. (2) On a steamship, the steel wire ropes that supported the funnels.

Sidelight A frame, usually of bronze, fitted into an opening in the side of a ship or part of the ship's structure, and which carries a thick glass (termed a 'light') for providing natural illumination to the space within. A sidelight normally carries the light in a secondary frame that is hinged or fitted in some way to permit its opening for ventilation.

Side Scuttle An opening in the side of a ship provided for the discharge of garbage, etc.

Sill, Window Frame The horizontal piece at the bottom of a window.

Siren, Steam A form of whistle in which the sound is produced by the action of steam in passing through corresponding openings in two concentric and oppositely revolving discs or cylinders. The pitch and intensity are raised and increased respectively with the speed of rotation. The steam is permitted to escape through a funnel-shaped opening or trumpet so as to increase and direct the volume of sound as much as is possible.

Sisal Cordage of stiff, rough fibers similar to hemp, but with coarser fibers. It is typically used for light tie-downs and other applications where great strength is not required.

Skidlight A sidelight mounted at or near deck level, providing light and air to a room on the deck below by means of a light-and-air trunk running at a downward angle.

Skylight A built-up frame of metal or wood having glass lights fitted in the top and installed over a deck opening for the purpose of furnishing light and, where the top covers are hinged, ventilation to the spaces below.

Skylight Coaming The vertical sides of a skylight frame, whether of steel or wood.

Skylight Cover The top of a skylight, having glass lights fitted in it and often hinged and operated from below. Brass rods are generally fitted over the glass for protection.

Skylight Gratings The gratings protecting the glass lights in a skylight cover. They are usually constructed of brass rods.

Skylight Lifting Gear A gear composed of rods, pinions, worms or gears, levers and hand wheel for opening and shutting a skylight cover from below. This gear should be designed to operate easily and to support the cover firmly when open.

Slipway (Slip) The space in a shipyard where a foundation for launching ways and keel blocks exists and which is occupied by a ship while under construction.

Slop Chute A chute hung over the ship's side or built into the ship with discharge through the ship's side, for discharging garbage overboard.

Sluice An opening in the lower part of a bulkhead fitted with a sliding watertight gate or door, having an operating rod extending to the upper or Upper Decks.

Sluice Cock A cock attached directly to a bulkhead to permit flow of a liquid directly from one compartment to another.

Small Stuff Very light cordage; twine.

Smoke Stack See 'Funnel'.

Soleing In small boat construction, the beveling of the upper, outer edge of a plank to form a landing for the next plank above.

Sole Plate The top plate of a foundation to which the base of a machine or piece of equipment is bolted.

Sounding Measuring the depth of water or other liquid, either in a tank or under the ship.

Sounding Line The fine piano wire or wire rope used with a sounding machine.

Sounding Machine A machine designed to take soundings by means of a wire drum connected to an electric motor and a read-out dial, thereby permitting soundings to be taken more rapidly than can be done by hand.

Sounding Pipes See 'Tubes, Sounding'.

Sounding Rod A light metal rod, graduated as desired, for lowering into a sounding tube to determine the depth of liquid in a compartment or tank.

Sounding Spar A spar designed to permit the lead from the sounding machine to drop well clear of the vessel's side.

Span A rope whose ends are both made fast some distance apart, the bight having attached to it a topping-lift, tackle, etc. A line connecting two davit heads so that when one davit is turned the other follows.

Spanner A form of open-head wrench for use with special fittings whose character is such as to preclude the use of the ordinary type of wrench.

Spar A pole serving as a mast, boom, gaff, yard, bowsprit, etc. Spars are made of both steel and wood.

Spar, Ridge A spar fitted between the stem head and stern post head on a lifeboat when its canvas cover is in place, to form a peak in the cover in order that water will run off on either side.

Spectacle Frame A single casting containing the bearings for and supporting the ends of the propeller shafts in a twin-screw vessel. The frame consists of arms of pear-shaped section extending outboard from each side of the centerline of the ship to bosses taking the bearings of the propeller shafts. These arms are usually inclined downward from the centerline at an angle of about 30° from the horizontal. The shell plating is worked outboard to enclose the shafts and is attached at the after end to the bosses and arms of the spectacle frame. They are used on steam yachts and large merchant vessels in place of shaft struts or brackets.

Spun Yarn Rough two-, three- or four-yarn, left-handed small stuff, made from old rope yarns loosely twisted together. It is extensively used aboard ship for coarser seizings, service, etc.

Stairs A built-in staircase aboard a ship. Also see 'Ladder'.

Stanchion, Bulwark A post or stanchion supporting a bulwark. The stanchions or stays are often made of plating having the inboard edge flanged or of channel bar, the stay making a slight angle with the bulwark plating and being clipped to the top of the bulwark and the deck.

Standing Rigging Lines that are permanently fixed to the ship, such as the stays that provide support for the masts. It can also refer to rigging that is temporarily fixed to the ship, such as for supporting cargo hoist lines. Standing rigging cannot be hauled upon and does not run through blocks or pulleys. Standing rigging is often fastened to the deck by splicing it with a thimble to a large rigging screw (turnbuckle) so that the tension can be adjusted as required.

Starboard Side The side of a vessel to the right when looking from the stern toward the bow.

Starboard the Helm See 'Port the Helm'. A term originally applied to the operation of putting the tiller over to right or starboard side causing the rudder and ship to turn to the left or port. Different countries and different branches of the marine have their own rules as to whether this order means to turn the ship to the right or left.

Starting Platform The location within an engine room from which the main engines are controlled and operated. Also referred to as the 'Maneuvering Platform'.

Stateroom A private room or cabin for the accommodation of passengers or officers. As a general term, is irrespective of class; in this book, refers specifically to First and Second Class passenger accommodations.

Stay (1) A rope, whether hemp or wire, that supports a mast in a predominantly fore-and-aft direction. (2) Any rope used as a tension member, as an awning stanchion stay, a canopy frame stay, etc. (3) A bar, pipe, or plate used as a support against racking, bending, etc. (4) To secure against movement by means of a stay or stays.

Steel and Iron Steel is primarily an alloy of iron and carbon, the carbon content ranging from a trace to nearly 2 per cent. It is capable of being cast into ingots or molds of various shapes. Steel may be classified with relation to the common method of manufacture employed such as crucible, open-hearth, Bessemer, Electric, etc., or by the use for which it is suitable such as machinery or tool steel.

Steel, Mild Steel having a carbon content of not more than 0.02 per cent, making it neither too brittle nor too ductile, and therefore strong, uniform in strength and easily worked.

Steerage The least desirable portions of a vessel as to accommodations for passengers and occupied by those paying the very lowest fare. Traditionally refers to the accommodations for emigrant passengers, regardless of the quality of the quarters provided.

Steerage Way The motion of a vessel when sufficient to permit maneuvering by the aid of her rudder.

Steering Engine A steam, electric or hydraulically powered machine used for turning the rudder and having its valves or operating gear actuated mechanically, hydraulically or electrically from the wheelhouse or other steering position.

Steering Gear Collectively, refers to the steering wheels, leads, steering engine and fittings by which the rudder is turned.

Steering Leads In small vessels, the shafting, ropes or chains transmitting motion from the steering wheel to the rudder stock.

Steering Wheel A wheel in which the spokes are continued through the rim for a distance sufficient to provide a good grasp for the hands and which is used for actuating the steering engine or the rudder. Where there are rope leads a drum is fitted to the hub of the wheel upon which the ends of the steering rope are wound and when the leads consist of shafting, gears transmit the motion from the axis of the wheel. In vessels that are not provided with a steering engine, this wheel usually has a diameter of about 5 or 6ft to provide leverage which is supplemented by gears or purchases in the steering leads. Large wheels, sometimes single, but usually two or more in tandem are also fitted as an auxiliary hand steering gear at or near the steering engine and sometimes on the deck above it.

Stem; Stem Post The bow frame forming the apex of the triangular intersection of the forward sides of a ship. It is rigidly connected at the lower end to the keel. In wood ships the main piece of the bow frame is called the stem. In small boat construction, the principle timber in the bow of a wooden boat, fastened to the end of the keel and extending to or above the gunwale.

Stern The after end of a vessel; the most distant part from the bow.

Stern Frame A heavy casting or forging attached to the after end of the keel to form the ship's stern. It includes the stern post, and the propeller post and aperture for the propeller in single- and triple-screw vessels. It also serves as a frame for rigidly connecting the converging sides of the ship at the stern.

Stern Post (1) The after part of the stern frame to which the rudder is attached; also called the 'rudder post'. (2) In small boat construction, the principle timber in the stern a wooden boat, fastened to the end of the keel and extending to or above the gunwale. The stern post is the vertical timber that carries the rudder.

Sternsheet In small boat construction, the inboard part of an open small boat aft of the last thwart.

Stern Tube The bearing supporting the propeller shaft where it emerges from the ship. It consists of a hollow, cast-iron or steel cylinder fitted with brass bushings, which in turn are lined with a lignum vitae or white-metal bearing surfaces upon which the propeller shaft, encased in a brass sleeve, rotates. In single-screw vessels the stern post or propeller post is bossed out and bored to take the stern tube which projects far enough aft of the post to take a large, flat nut. The forward end of the stern tube is connected by a flange to the after peak bulkhead, which in conjunction with a stuffing box fitted around the shaft, makes a watertight joint at this point. Water can enter the stern tube from the after end through grooves in the lignum vitae or white-metal bearings and has been found to be a suitable lubricant when it is not mixed with sand or mud. The stern tube in single-screw vessels takes the heavy weight of the propeller and must also withstand the side thrust caused when blades are broken off or come out of water. In twin-, triple- and quadruple-screw vessels in which the shafts remain exposed after exiting the hull proper, there is generally a strut or bracket aft of the tube to support the screw; on vessels in which the shell plating is worked around to enclose the wing shafts, both the after end of the stern tubes and the weight of the propellers are supported by the spectacle frame or brackets. In vessels these last-named vessels, the stern tubes are supported by the side framing and a bulkhead worked at the forward end of the tube. On account of the angle they make with the shell plating the tubes are generally longer than in single-screw vessels.

Stiff, Stiffness The tendency of a vessel to remain in the upright position or a measure of the rapidity with which she returns to this position when inclined by any external force. The degree of stiffness is directly affected by the value of the vessel's metacentric height.

Stiles The vertical sides of a window frame.

Stokehold That portion of the ship's boiler room from which the fires are fed and cleaned. Also called the 'Firing Aisle'.

Stokehold Ventilator A ventilator supplying air to the stokehold or boiler room. If forced draft is supplied on the closed stokehold system the ventilator supplies air to the forced draft blowers, the quantity of air being that required for combustion in the boilers.

Stoker (1) An automatic gear for feeding coal to the fires in a boiler. (2) A term applied to a Fireman.

Store Rooms Any space or compartment in which are stowed the stores and supplies that are used aboard the ship.

Stow To pack away, to lash in place, or to otherwise secure in position for a sea voyage.

Stowage The proper distribution and securing of cargo in a vessel so as to avoid damage to either cargo or vessel by the shifting of cargo or by the undesirable conditions of trim and stability resulting from such a shift.

Strake A term applied to a continuous row or range of plates. The strakes of shell plating are usually lettered, starting with 'A' at the bottom.

Strake, Bilge A strake of outside plating running in the way of the bilge.

Strake, Bottom Any strake of plating on the bottom of a ship that lies between the garboard and bilge strakes.

Strake, Doubling A strake made up of two thicknesses of plates. Also to the extra range of plates fitted in conjunction with the regular strake. The sheer strake and topside plate are often doubled amidship for extra strength.

Strake, Drop A strake that is terminated before it reaches the bow or stern. The number of strakes dropped depends on the reduction of girth between the midship section and the ends.

Strake, Garboard The strake of shell plating adjacent to the keel. This row of plates act in conjunction with the keel to impart longitudinal strength, with these plates made heavier than the other bottom plates.

Strake, Inner The inner strake of an in-and-out system of shell plating. The strakes adjacent to the molded frame line.

Strake, Limber The inside strake nearest the keelson in wood ships.

Strake, Outside (1) The outer strake of an in-and-out system of shell plating. (2) The strakes which lap on the inner strakes and which are the thickness of the plating outside of the molded frame line.

Strake, Topside (1) The strake next below the upper or strength deck sheer strake. (2) The second range of shell plating down from the upper or strength deck.

Stretcher See 'Foot Spar'.

Stringer (1) A term applied to a fore-and-aft girder running along the side of a ship. There are three sets of fore-and-aft girders in the framing of a ship: 'longitudinals', or 'keelsons', which are the approximately vertical strength members in the bottom; 'stringers' or 'side stringers', which are the approximately horizontal strength members on the sides; and 'girders', which are the approximately vertical members under the decks. The word 'stringer' is sometimes used to apply to all three groups but it should only be used for the side girders. (2) The outboard strake of plating on any deck. (3) In small boat construction, a piece of wood running from the stem to the stern post along the inside of the timbers. (4) The side pieces of a ladder or stair case into which the treads and risers are fastened.

Stringer Angle Bar The angle bar connecting a deck stringer plate to the outside plating or bulwark. They are usually made up of short lengths running between frames; these are also referred to as 'shell bars'. A continuous angle bar connecting the inner flange of the frames to the stringer plate is sometimes called a stringer bar.

Stringer, Awning Deck A term applied to the outboard strake of plating on the Awning Deck.

Stringer Bar A continuous fore-and-aft strength member made up of angle bars or shapes attached to the inside flanges of the frames. Also applied to the angle bar connecting a stringer plate to the shell or frames, in which case the name of the stringer is usually placed before it, as Main Deck stringer bar.

Stringer, Bilge In small boat construction, the lowest stringer running fore-and-aft from the stem to the stern post.

Strum Box See 'Rose Box'.

Stuffing Box A fitting designed to permit the free passage or revolution of a rod or pipe while controlling or preventing the passage of steam, water, etc.

Surmount *(Architectural design)* To furnish with something placed on top or above.

Surround *(Architectural design)* Enclosed or bordered by.

SWG See 'Wire Gauge, Standard'.

Switch, Knife A device with one or more hinged copper blades equipped with a handle and so arranged as to open or close an electric circuit.

Synchronous Converter An electrical rotary machine having one armature and with the windings so arranged that it operates on alternating current and delivers direct current, or vice versa. Sometimes called a rotary converter.

Synchronous Motor See 'Motor, Synchronous'.

Tackle Any combination of ropes and blocks that multiplies power. (Pronounced 'tay-kel')

Taffrail A term applied to the rail around the top of the bulwark or rail stanchions on the after end of the Weather Deck, be it upper, main, raised, quarter or poop.

Tail Shaft See 'Propeller Shaft'.

Tank, Ballast A space or compartment which may be filled with water to add weight when it is necessary to produce a change in trim or in the stability of the ship.

Tank, Peak Narrow V-shaped compartments at the bow and stern of the ship in which no cargo is stored, but which may be filled with water to alter the longitudinal inclination, or 'trim' of the ship.

Tank, Sanitary A tank arranged to receive the discharge from the various sanitary or plumbing fixtures located below or close to the water line and which cannot drain overboard by gravity. Contents of sanitary tanks are pumped overboard.

Tarpaulin A pliable, canvas hatch cover. One or more tarpaulins are stretched over the wooden hatch covers and the edges are held in place by battens wedged into cleats on the hatch coaming. Also applied to pieces of canvas used as a shelter for workmen or as a cover for deck equipment.

Taut The condition of a line or chain when under sufficient tension to cause it to assume a straight line, or to prevent sagging to any appreciable amount.

Tee Bar (or T-Bar) A rolled shape, generally of mild steel, having a cross-section shaped like the letter T. In ship work it is used for bulkhead stiffeners, frame legs, floor clips, etc. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Telegraph An apparatus, either mechanical or electrical, for transmitting orders from a ship's bridge to the engine room, steering gear room, or elsewhere, between boiler rooms, and from the engine room to the boiler rooms. The transmitting apparatus, operated by the sender, is termed the transmitter, and the receiving apparatus, the indicator. A gong is usually fitted in order to call attention to the movement of the indicator.

Telemotor A device for operating the valves of the steering engine from the pilot house, wheelhouse or bridge, either by fluid pressure or by electricity. When fluid pressure is utilized, two leads of pipe are necessary so that the fluid may move aft in one pipe and forward in the other, or vice versa. The movement is provided for by a small pump or ram actuated by the steering wheel.

Telltale An indicating device employed on automatic machinery or in a specific operation which gives audible or visual indication, or both, as to the exact time a specific function is begun or completed.

Telltale, Rudder A term applied to an instrument that indicates the angle of the rudder with the centerline of the ship. It is generally fitted in front of the steering wheel.

Tender (1) A small boat, usually power-driven, used for purposes of general utility by the personnel of a large vessel. (2) a purpose-built vessel that ferries passengers, baggage and light cargo or mail from the shore to a larger vessel at anchor.

Tenoning Machine A power operated machine which usually has a hand feed and cuts a tenon on pieces of timber by means of knives carried in short revolving cutter heads.

Terminal (1) That part of an electrical fixture, typically a screw fitting, designed to connect with a wire supplying electrical power. (2) An ornamental figure or object placed at the end of a larger structure or at the top of a decorative post; a finial.

Thermometer An instrument for measuring the degree of heat or temperature.

Thermotank A box or tank containing steam coils through which air for ventilation is heated in passing.

Thimble An iron ring or an oval or heart-shaped fitting whose outer surface is concave in order that it may be held in place when worked into an eye spliced into a rope. It serves as a lining to prevent the chafe of a hook, shackle, pin, etc.

Thole Pins A pair of metal or hardwood pins fitted into vertical holes in a gunwale and spaced several inches apart to serve as an oarlock. *Titanic*'s lifeboats were fitted with thole pins for all oars except the steering oar, which was fitted to a crutch.

Thrust Bearing A bearing designed primarily to take the propeller thrust from the shaft and transfer it to the structure of the ship. It is constructed with a series of rings and channels for the reception of the collars of the thrust shaft. The rear faces of the thrust bearing rings and the forward faces of the thrust shaft rings bear on one another when the screw is turning ahead. The opposite takes place in backing. The faces of the bearing channels are usually of white metal so as to provide steel-on-white-metal wearing surfaces. At the forward and after ends of the thrust bearing are bearings of the usual type fitted to carry the weight of the thrust shaft. Special methods of lubricating and cooling are provided.

Thrust Block The unit which contains the thrust bearings and also the bearings which support the thrust shaft.

Thrust Shaft That length of shafting which is fitted for the purpose of transferring the thrust of the propeller to the thrust bearings. This is effected by means of circular collars or rings worked on the thrust shaft.

Thrust Stool The seating upon which the thrust block is supported. In addition to supporting the weight of the thrust block and shaft, it has to substantially constructed in order to transfer to the hull the thrust developed by the propeller and delivered through the thrust shaft and block, while resisting both torsional forces and considerable fore-and-aft straining, especially in heavy seas.

Thwart In small boat construction, a seat fastened from gunwale to gunwale in a small boat to add rigidity and provide for seating.

Thwart Knee In small boat construction, a brace fitted beneath a thwart to provide support to the thwart where it meets the gunwale. See also 'Knee'.

Tiller The arm attached to the rudder stock to operate the rudder.

Tongue-and-Groove A plank, one of the edges of which is cut away to form a tongue and the other recessed to form a groove. The tongue on one plank is matched with the groove on the other. Also called 'matchboarding' and 'feather-and-groove'.

Tonnage, Gross The entire internal cubic capacity of a vessel expressed in tons of one hundred cubic feet each.

Tonnage, Gross Registered The gross tonnage as entered on the register or other official certificate of the tonnage of the vessel.

Tonnage, Net The internal cubic capacity of a vessel which remains after the capacities of certain specified spaces have been deducted from the gross tonnage. These deductible spaces include principally crew's quarters, working spaces and machinery compartments.

Tonnage, Net Registered The net tonnage as entered on the register or other official certificate of the tonnage of a vessel.

Tons Per Inch of Immersion The number of tons of additional weight required to immerse a vessel one additional inch of draft. The approximate tons per inch of immersion at any draft for salt water is equal to the area of the waterplane in square feet divided by 420.

Torsional Stresses Those stresses produced by transverse moments applied to a ship's structure (for instance, by a quartering sea) resulting in a twisting of the structure about a longitudinal axis.

Transverse At right angles to the ship's longitudinal centerline.

Treble Purchase A purchase in which two treble blocks are used.

Treillage *(French)* Latticework or trellisework, or of a trelliswork design.

Trim The longitudinal deviation of a vessel from her designed waterline at a given draft. When expressed in feet and inches it is equal to the sum of the distances that points on the waterline at the bow and stern are above or below the designed waterline at the mean draft at which the vessel is floating. The variation in a vertical direction of the forward and after extremities of the actual position of a vessel's plane of floatation from its designed position.

Trim by Head That condition of trim in which a vessel inclines forward so that her actual plane of flotation is not coincident with or parallel to her designed plane of flotation.

Trim by Stern That condition of trim in which a vessel inclines aft so that her actual plane of flotation is not coincident with or parallel to her designed plane of flotation.

Trimmer A non-skilled Engine Department rating whose primary responsibility was to load, stow and distribute coal throughout the ship's bunkers. At sea, the Trimmers continued to evenly redistribute coal as the supply was used, ensuring that a continuous supply was always available at the bunker doors. In doing their job, the Trimmers evenly adjusted and spread out – or 'trimmed' – the piles of coal in the bunkers, which is where the name comes from.

Trunk A vertical or inclined shaft formed by bulkheads or casings extending through one or more decks, around openings in the decks, through which access can be obtained, cargo stores, etc., handled or ventilation provided without distributing or interfering with the contents or arrangements of the adjoining spaces.

Trunk, Ventilating Trunks through which air is led for supplying fans and blowers, or through which heated air is allowed to escape.

Tubes, Sounding Small pipes leading vertically up from a tank and arranged with the lower end opening into the tank so that the liquid rises in the pipe so its height can be measured by lowering a sounding rod into the pipe.

Tumblehome The decreasing of a vessel's beam above the waterline as it approaches the rail. (The opposite of flare.)

Tunnel Recess The enlarged end of a shaft tunnel. At the forward end this enlargement is termed the thrust recess and at the after end the stuffing box recess.

Tunnel, Shaft A long narrow compartment running from the propelling machinery to the stern tube and containing the line shafting and its bearings. Fitted in order to provide access to the shaft and shaft bearings as well as to protect the shafting from the cargo in the after holds. Also called a 'Shaft Alley'.

Turbine A machine in which the kinetic energy of the steam is transformed into direct rotary motion. A reciprocating engine produces work by the relatively slow overcoming of resistance by the pressure of the steam up to the cut-off and by the hyperbolic expansion of the steam up to the release, while a turbine does its work through the impulse reaction of steam or steam jets at high velocity on rotary vanes.

Turbine Blades The vanes either on the rotor or the casing which are subject to and directly affect the travel of the steam through the turbine.

Turnbuckle See 'Rigging Screw'.

'Tween Decks A term applied to the space between any continuous decks.

'Tween Deck Tonnage The enclosed space between decks expressed in tons of one hundred cubic ft.

Twine Small cotton or flax cord or thread used by sail-makers in working on canvas.

Under-Deck Tonnage The enclosed volume of a vessel below the Tonnage Deck expressed in tons of one hundred cubic ft.

Underway As defined by navigation rules, a vessel is under way 'when she is not at anchor, made fast to the shore or aground'. Generally speaking, though, it means that the ship is proceeding on a course. Also see 'Way'.

Unship To remove anything from its accustomed or stowage place; to take apart.

Variation The error in a compass reading, measured in degrees, resulting from the compass needle being attracted toward the Earth's magnetic North Pole instead of the geographic North Pole on which charts are based. Also called 'magnetic declination'.

Valve A mechanical contrivance used for controlling or shutting off the passage of air, steam, water, etc., into or out of a boiler, cylinder, tank, compartment; or through a pipe line. Also see 'Cock'.

Valve Chest A chamber or case in which a valve or set of valves works.

Valve, Reducing A valve located in the steam supply line in order to reduce the pressure of the steam supplied to auxiliaries. Such reductions are made in the interest of production economy and steadiness of operation.

Valve, Reducing, Steam A self-acting valve so arranged by means of diaphragms and springs that the steam pressure will be reduced after passing through the valve.

Valve, Relief A valve designed to open automatically at a desired pressure. They are installed on the cylinders of reciprocating engines and sometimes on the valve casings.

Valves, Safety Valves arranged to open at any predetermined pressure and, by permitting the escape of vapor, gas or other medium, to prevent explosion or damage to a boiler, tank or other container.

Valve, Sea A valve located at or near the outside plating of a vessel to supply sea water to the pumps and for flooding the ballast tanks, etc.; also for discharging water overboard from bilge pumps, ballast pumps, condenser circulating pumps, boiler blow-down connections, etc.

Ventilating System A system consisting of light metal pipes, blowers, special intakes, etc., for supply of fresh air to and removing foul air from the various compartments in a vessel.

Ventilation The process of providing fresh air to the various spaces and replacing foul or heated air by fresh air.

Ventilation, Mechanical Ventilation supplied by fans or blowers and sometimes by compressed air, the fans being operated by electric motors, steam engines or other mechanical means. The ventilation in this case is forced or induced by the fan through a pipe or pipes to one or more compartments whereas natural ventilation would require a separate pipe and cowl for each compartment.

Ventilation, Natural Ventilation depending on the wind blowing into or past the opening of a ventilator to effect a downward draft or induce an upward draft, and also on the natural tendency of heated air to rise and escape through the pipes and trunks provided.

Ventilation, 'Thermotank' System A ventilation system in which the air is heated by passing over or around tubes through which steam is circulated. The box or tank containing the steam coils is called the Thermotank.

Ventilators, Bell-Mouthed or Cowl Terminals on open decks in the form of a 90° elbow with enlarged or bell-shaped openings, so formed as to obtain an increase of air supply and to increase the velocity of air down the ventilation pipe when facing into the wind, or to induce an upward draft when facing away from the wind.

Ventilators, Goose-Neck or Swan-Neck Terminals consisting of a 180° bend used only on ends of exhaust pipes and so shaped as to make the clogging of the outlet difficult.

Voice Tube A tube designed for the carriage of the human voice from one part of or station in the ship to another.

Volt The practical unit of electromotive force. It represents that pressure which produces a current of 1 ampere in a resistance of 1 ohm.

Voltage Regulator An instrument usually mounted on a switchboard for the purpose of keeping the voltage at a predetermined value.

Voltmeter An instrument for measuring the difference in potential between two points in a circuit.

Wainscot (1) A facing or paneling, usually of wood, applied to the walls of a room. (2) the lower part of an interior wall when finished in a material different from that of the upper part.

Warp (1) A light hawser or tow rope. (2) To move a vessel along by means of lines or warps secured to some fixed object.

Warping (1) A term applied to the operation of moving a vessel from one place to another about a dock or harbor by means of hawsers. (2) The operation of changing a vessel's berth when it is not performed by tugs or its own propelling machinery.

Wash Plates (1) Plates fitted longitudinally between floors for the purpose of checking the flow of bilge water when the vessel is rolling. (2) Plates fitted along the base of railings to prevent water from washing over the edge onto the deck below.

Wash Port See 'Port, Wash'.

Watches (1) Nautical divisions of time, usually four hours each, for standing watch or being on deck ready for duty. (2) The division, usually one-half, of the officers and crew who together attend to the working of a vessel during the same watch. These are designated as the starboard and port watches, each of which is alternately on duty.

Water-courses A term applied to limber holes and to gutters in the lower portions of compartments between limber holes.

Watertight Bulkhead See 'Bulkhead, Watertight'.

Waterway On wooden ships, the margin plank running along the edges of the decks adjacent to the inside faces of the frames. This timber is always thicker than the regular deck planking. On steel ships with planked decks, the gutter formed along the sides of a deck by the waterway and stringer angle bars.

Watt The unit of electrical power; the power dissipated by a current of 1 ampere flowing across a resistance of 1 ohm. One watt equals 0.00134 horsepower.

Wattmeter An instrument for measuring electrical power.

Way Movement of a ship. When a ship is moving it is said to 'have way on'. Also see 'Underway'.

Wearing See 'Rising'.

Wharf A structure built on the shore of a harbor, river, canal or the like and extending out into deep water so that vessels may lie close alongside to receive or discharge cargo or passengers.

Wheel See 'Steering Wheel'.

Wheelhouse A shelter built over the steering wheel. The term is generally used relative to the house in which a hand steering wheel is located.

Whistle A signaling and warning device through which high pressure steam or air is forced to produce a loud sound.

Whistle Control, Electric To eliminate the danger of breakage to the whistle rope and to reduce the physical labor required to blow the whistle frequently in fog, the electric control has been developed. It consists of a controlling switch located in the pilot house and on the bridge and electrically connected to a relay. The closing of the control switch in the pilot house causes the relay to close which completes a circuit through a solenoid located just below the whistle valve. The pull of this solenoid operates the whistle valve.

Whistle Pull A cord or rope of small diameter extending from the whistle to the pilot house and used to operate the same.

Wildcat See 'Cable Holder'.

Winch A hoisting or pulling machine fitted with a horizontal single or double drum. A small drum is generally fitted on one or both ends of the shaft supporting the hoisting drum. These small drums are called gypsies or winch heads. The hoisting drums are either fitted with a friction brake or are directly keyed to the shaft. The driving power is usually steam or electricity but hand power is also used. A winch is used principally for the purpose of handling, hoisting and lowering cargo from a dock or lighter to the hold of a ship and vice versa. It is also used to top the booms, take up on lines in miscellaneous work aboard ship, in warping a ship into dock and in some cases for working windlasses and pumps by messenger chain.

Windlass See 'Windlass, Steam'. A device for hoisting or hauling by means of a rope or wire wound on to a horizontal drum or barrel.

Windlass, Steam An apparatus in which horizontal drums are operated by means of a steam engine for the purpose of handling heavy anchor chains, hawsers, etc. The engines are usually of the simple reversible type, the cylinders being variously disposed and actuating worm shafts which in turn operate the gypsy and wildcat shaft through the worm wheels.

Wing Tanks Tanks located outboard and usually just under the Weather Deck, or in a double bottom outside of the margin plates. When of the former type, they are sometimes formed by fitting a longitudinal bulkhead between the two uppermost decks and sometimes by working a diagonal, longitudinal flat between the ship's side and the Weather Deck.

Wire Gauge, Standard(SWG) A standard series of sizes arbitrarily indicated by numbers corresponding to specific diameters. Standard Wire Gauge numbers are also used to specify the thickness of sheet metal.

Wormed The initial stage of protecting a line by worming, parceling and serving, in which the channels between strands are filled in by lengths of 'small stuff', led along the lay of the rope in a spiral fashion prior to parceling, to give the rope a more cylindrical shape. Worming, parceling and serving is a multi-layer system of protection against deterioration and chafing for the ends of lines.

WTB See 'Bulkhead, Watertight'.

Yardage A term applied to the length per unit of weight of cordage.

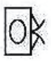
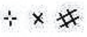
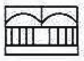
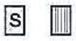
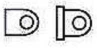
Yaw The act of sheering suddenly and uncertainly from a vessel's course. It may be caused by poor steering, strong winds, by the condition of the sea, or by the characteristics of the vessel's underbody or by any combination of the foregoing.

Yoke A frame or bar having its center portion bored and keyed or otherwise constructed for attachment to the rudder stock. The connecting rods from the steering engine or the leads from the steering gear are connected to each end of the yoke for the purpose of turning the rudder.

Yoke Lanyards Line attached at the extremities of the yoke and extending to the stern sheets for use in steering a small boat.

Zee Bar (or Z-Bar) A rolled shape, generally of mild steel, having a cross-section shaped like the letter Z. In ship work it is used for frames and bulkhead stiffeners. The size is denoted by dimensions of cross-section, thickness, and also in weight per running foot.

Key to abbreviations and symbols on General Arrangement plans

AE -	ASH EJECTOR	S ON BOAT DECK -	SKID LIGHT
B -	BUNK	SB -	SIDE BOARD
BR -	BAG RACK	T OR TE -	TUNNEL ESCAPE
CS -	COAL SHOOT	TV -	TUNNEL VENT
D -	CHEST OF DRAWERS	V -	UTLEY'S VENTILATING SIDELIGHT
DC -	DIRECT CONTACT	V -	VENT
DT -	DRESSING TABLE	W -	WARDROBE
DRES -	DRESSER	WP -	WASH PORT
DRS (BUNKS) -	DRAWERS	WT -	WATERTIGHT
DP ON TANK TOP -	DRAIN POT	WTB -	WATERTIGHT BULKHEAD
FE -	FIREMAN'S ESCAPE	WTD -	WATERTIGHT DOOR
FL -	FOLDING LAVATORY	WR -	WARDROBE ROOM
FW -	FRESH WATER	WT -	WRITING TABLE
GI -	GALVANIZED IRON		DUTCH DOOR
H -	HEATER	 VAR.	LAVATORY SINK
H -	HOIST	VAR.	SINK
HP -	HOT PRESS	 VAR.	UPHOLSTERY
L OR LK -	LOCKER	 VAR.	URINALS
L&A -	LIGHT & AIR		WALL SEAT TEAK
MP -	MOORING PIPE		WALL SEAT UPHOLSTERED
PT -	PIPE TUNNEL		WASH BASIN
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Subjects Covered in Volume 2 of Titanic: The Ship Magnificent

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Interior Design and Furnishings, Ship Joinery, Stairs, Ladders and Doors
Sanitary Appliances
Culinary, Commissary and Service of Plate
Boat Deck
A Deck (Promenade)
B Deck (Bridge)
C Deck (Shelter)
D Deck (Saloon)
E Deck (Upper)
F Deck (Middle)
G Deck (Lower)
Orlop Deck, Lower Orlop and Tank Top
Appendix: Passenger Accommodations by Deck and Class
Appendix: Crew List
Glossary of Ship and Shipbuilding Terms

About the Authors

BRUCE BEVERIDGE (US) has been a historian for many years, centering on early civilizations, the Crusades, and famous ships. He is also the senior historical archivist for his local community library and spends his time away from *Titanic* working on local history projects. Bruce is one of the foremost visual and technical historians of the *Olympic*-class ships and has advised on *Titanic*'s specifications for exhibitions, publishing companies, professional modeling firms, the Danbury Mint, museums, television production companies, the auction firm of Henry Aldridge & Son and other organizations. Bruce's highly sought-after General Arrangement plan of the ship, released in 2003, is the most highly detailed and accurate plan released to date and has subsequently been used by dive teams investigating the wreck. He co-authored *Titanic or Olympic – The Truth Behind the Conspiracy* in 2004, *Titanic in Photographs* and the *Report into the Loss of the SS Titanic: A Centennial Reappraisal* in 2011.

SCOTT ANDREWS (US) first became aware of the story of *Titanic* at the age of four when he was captivated by a picture of the ship published in *Reader's Digest* as part of a condensed version of Walter Lord's *A Night to Remember*. Between having it read to him and then seeing the J. Arthur Rank movie of the same name, he admits he became thoroughly and hopelessly hooked. Scott's primary interest in *Titanic* centers on the engineering aspects of the ship – her design, construction and propulsion machinery. He is a trustee of the Titanic Research and Modeling Association, and also co-authored *Titanic in Photographs*. His interests outside *Titanic* include pipe organs and organ building and restoring antique cars.

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DANIEL KLISTORNER developed an interest in *Titanic* during the early 1990s after reading a newspaper article about an expedition to the wreck. Daniel's interest in *Titanic* centers around passengers and accommodations. His research of exacting details has been the key to his comprehensive understanding of *Titanic*'s passenger areas, interiors and fittings as well and he is a recognized authority in this area, particularly the first class staterooms and their styles of design. He has provided consultation for several authors and auction houses as well as Bruce Beveridge's General Arrangement plans of the ship, and is a co-author of *Titanic in Photographs*. Daniel resides in Sydney, Australia, and is an avid traveler.

ART BRAUNSCHWEIGER has had a long-standing interest in maritime and naval history, focusing on the British Navy of the period 1750–1820, Second World War submarine warfare in the Pacific, the Atlantic convoys of the Second World War and, of course, *Titanic*. He has consulted for TIME-LIFE books on *Titanic* and has authored several research articles in print and online. Art also co-authored *Titanic in Photographs* and the 2012 rewrite of *Titanic or Olympic – Which Ship Sank?* Art is an experienced wreck diver and devotes his spare time to model ship building and beekeeping. He lives in Bridgewater, New Jersey, with his wife and two Labrador Retrievers.